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The Bourdon Pressure Gauge. By JOHN T. HAWKINS, First Asst. Engineer, U. S. Navy.

On page 365 of the December number of the *Journal* for 1865, I find an article on the Bourdon Pressure Gauge, by John D. Van Buren, in which he exhibits very conclusively that one of the causes of the motion of the free end of a flattened tube, arranged as in Fig. 1, resulting from internal pressure, is the tendency of the tube to assume a cylindrical form, or rather, a circular form of transverse section; and that the motion produced by an excess of external pressure is the result of its tendency to still further depart from the circular form of transverse section, in the first case increasing, and in the last diminishing its volume for a constant periphery.

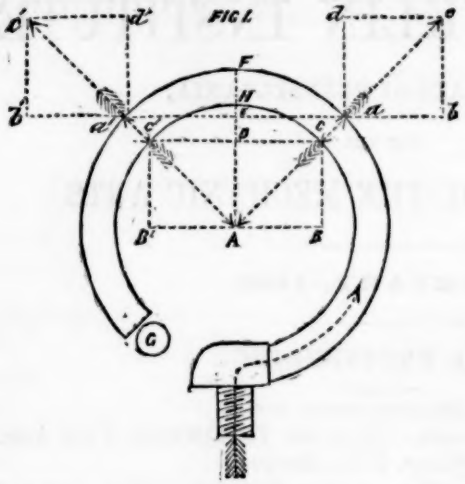
So far as that demonstration goes, Mr. Van Buren is undoubtedly correct; but he thereafter, in an appended note, attempts to disprove the commonly accepted theory of what is certainly one of the causes of the motion of the free end of the tube, and thereby falls into a very common error: that of making one natural principle solely responsible for phenomena really involving several.

It was not necessary, in order to establish the soundness of his reasoning in the original article, to attempt to upset so unceremoniously an equally sound principle, and one that can be easily shown to be one of the causes of the known actions of this gauge.

It is proposed to show that internal pressure does diminish the curvature of this flattened tube, by virtue of the greater area contained in the outer circumference, notwithstanding the statement that this would enable us to "make motors (prime) of our boots by tugging at

the straps," and that a hollow crescent with an excess of internal pressure would "fly even to its heavenly prototype."

Let Fig. 1 represent the tube of a Bourdon gauge, except that a transverse section of it be circular, as shown at G; in which case, of course, its volume cannot be increased by any change in the form of its transverse section. Take any two points C C′ upon the interior, and two others *a a′*, upon the exterior circumference, such that the lines C *a* and C′ *a′* shall radiate from the centre of curvature A. Let C A, *a* c, C′ A, and *a′ c′* represent respectively the direction and intensity of the internal pressures at those points, all being equal. Each of these forces may be resolved into two, one acting vertically and the other horizontally. Let us see the effect of the eight components of these four forces. The horizontal components *a b* and *a′ b′* operate to diminish the curvature of the line *a* F *a′*, acting upon a lever = E F = ver sin of the angle C A D for radius = A F. The components C D and C′ D in like manner operate to increase the curvature of the line C H C′, acting upon a lever = D H = ver sin of the same angle for the lesser radius A H. The components *a b* and *a′ b′*, then, preponderate to diminish the curvature of *a* F *a′*. Again, the components *a d* and *a′ d′* acting vertically operate to diminish the curvature of *a* F *a′* upon a lever = *a* E, or *a′* E = sin of the angle C A D for radius = A F, while the components C B and C′ B′ operate to increase the curvature of C H C′ upon the lesser lever C D or C′ D = sin of the same angle for the lesser radius A H, the preponderance being again in favor of diminishing the curvature of *a* F *a′*.



The result of this is, plainly, to straighten the segment of the tube included between the points taken, and yet the sum of the vertical components acting upward are exactly equal to those acting downward, and the sum of the horizontal components acting in one direction exactly equals the sum of those acting in the other; so we see that the thing would not take its flight in any direction if free to move, notwithstanding that there really is a greater area acted upon by the internal pressure in the line *a* F *a′* than in C H C′, and that the same is the case for every other segment of the tube.

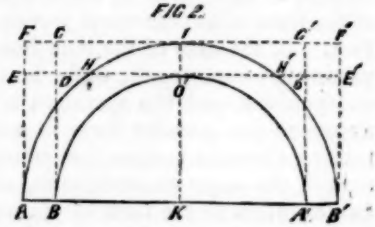
Now, if the tube have an elliptical transverse section, with the major axis perpendicular to the plane of its curvature, the same conditions obtain, except that the material of the tube is in such position that

it can be straightened with greater facility, the diminished difference in the radii A F and A H being compensated for by the increased major axis of the transverse section, with a decrease in the amount of material presented edgewise to resist its becoming straightened; thus the operation of the forces shown are the most effective in assisting to produce the motions of the gauge, the more the transverse section departs from the circular form in this particular direction.

It only becomes a question, then, whether the straightening of the tube is brought about most by the tendency to assume a circular transverse section, in order to increase its volume, or by the operation of the pressure upon the excess of area contained in the outer circumference.

Let Fig. 2 represent a semi-circular tube, having a circular transverse section, as in Fig. 1, the ends A B and A′ B′ being closed, and conceive an excess of pressure to exist within it. The sum of the forces acting vertically downward upon all the surface comprised in the ends, and the inner semi-circumference, may be represented by the projecting line A B′, and in like manner those acting upwards upon the outer semi-circumference by the equal projecting line F F′, the upward and downward forces are therefore equal, and this form of the instrument *could not get away from us* in either of these directions.

FIG 2.



Again, all the forces acting horizontally against the interior of the outer semi-circumference may be divided into two equal and opposite ones, represented by the projecting lines F A and F′ B′, and in the same manner the forces acting horizontally upon the convex surface of the interior semi-circumference may be represented by the projecting lines D B and D′ A′; and, therefore, we way release the instrument unconditionally, *without fear of its betaking itself off to parts unknown.* Yet we see that the force represented by the projecting lines F A and F′ B′ exceed those represented by D B and D′ A′ by the quantity represented by the lines F E and F′E′. The result of this is clearly that the ends of the tube must be separated by internal pressure, although no alteration in the form of its transverse section can possibly increase its volume with a constant periphery. This is a natural consequence of the undeniable fact that the outer circumference of a Bourdon, or any other curved tube, contains a greater area than the inner one.

To follow Mr. Van Buren's own illustration in the appended note: Suppose the parallelogram C K B′ E′, Fig. 2, to represent by its sides C K and E′ B′ the forces acting horizontally "to push the elementary areas" C A′ and H′ B′ "in the direction of the parallel lines" C E′ and B′ K "are equal and opposite," these forces "being measured by the equal projections" C K and E′ B′, and that the same is the case with the parallelogram C K A E and "the elementary areas" C B and H A.

On the same principle the forces represented by the projecting lines F E and F′ E′ tend only "to push the elementary areas" I H′ and I H *asunder* "in the direction of the parallel lines" C E and C E′.

The lines F E and F′ E′, then, represent the value of two forces for which there are no compensating ones in the opposite directions, and therefore operate to separate the ends of the tube, acting upon a lever equal to one-half the line C I, by means of the greater area exposed to the pressure upon the inside of the semi-circle A H I H′ B′, over that contained in the semi-circle B C A′.

It is to be understood that the writer does not deny that the tendency of the flattened tube to assume a circular transverse section is one of the causes of the motion produced; for he has seen it proved by experiment, that a tube flattened such that the major axis of its transverse section was parallel to the plane of its curvature, underwent an increase of curvature from internal pressure. The position of the material of the tube, however, in this case is most unfavorable to the operation of the force upon the excess of area contained in the outer circumference to straighten it, while it is quite as favorable to an alteration of the form of its transverse section as when flattened in the other direction. In the case of the true Bourdon tube the two causes operate to produce the one result, while in the experiment mentioned they are antagonistic, and the operation of causing the transverse section to approach the circular form is much easier performed than that of making the tube become less convex by the force due to the greater area of the outer circumference, and therefore would prevail until, by an alteration in the form of its transverse section, the two forces became equal, from which point the other force would preponderate, and the curvature of the tube would begin to diminish.

On the Law of Density of Saturated Steam Expressed by a New Formula. By Thomas Rowe Edmonds, B.A., Cantab.

From the Philosophical Magazine, July.

The expansive force of a unit weight of saturated steam, according to temperature, is usually measured by the product of the pressure P in pounds to the square foot, multiplied by the volume V in cubic feet occupied by one pound weight of such steam. The product P V represents the work done or resistance overcome in foot-pounds, and is equal to the effect produced by a constant force P pounds driving a piston, whose area is one square foot, through the linear space represented by the number which expresses V in cubic feet. When the laws of pressure and volume are both known, the law of expansive force represented by the product P V will be known also. But such a compound will not be entitled to the appellation of a third law, if the two formulas for P and V, when united, do not yield for result a third formula equal in simplicity to either of the two constituent formulas.

The pressure P of saturated steam, appropriate to every temperature, from — 30° to + 230° Centigrade, has been satisfactorily and

accurately determined through the observations of M. Regnault, published in the year 1847. The law of pressure deduced from these observations has been investigated in the *Philosophical Magazine* for March, 1865, and the formula indicating the law has been found to be

$$\text{hyp. log. } \text{P} = \frac{a\,a}{n}\left\{1-\left(1+\frac{t}{a}\right)^{-n}\right\}.$$

This formula was directly obtained from the table of pressures adopted by M. Regnault, through observing that the differential co-efficient of log. P, at any temperature t, was always represented by

$$\frac{d \log. \text{P}}{d\,t} = a\left(1+\frac{t}{a}\right)^{-\frac{1}{k}}$$

the exponent $\frac{1}{k}$ $(=n+1)$ being equal to the number 2·302585, which is the hyperbolic logarithm of 10.

The first and only satisfactory observations made for determining by experiment the density of saturated steam at various temperatures, are those of Messrs. William Fairbairn and Thomas Tate. They are published in the *Philosophical Transactions* of the year 1860. The difficulties are great in the way of making correct observations on the density of saturated steam in free communication with water. Such steam has not yet been obtained in a pure state, there being always an admixture of water with such steam. Part of the water is suspended in the form of cloud or mist, and part is pressed as a film of fluid against the sides of the containing vessel. Messrs. Fairbairn and Tate appear to have overcome the chief impediments to correct observation by the use of their "saturation gauge." On examining the results obtained, it will be found that the law of progression, according to temperature for the density as given by these observations, is not much less regular than the law of progression for pressure as given by the observations of M. Regnault. It will be found that the function of the variable t, involved in the law of density, is identical with the function of the variable t, involved in the law of pressure. The differential co-efficient of log. P has already been found to be

$$+a\left(1+\frac{t}{a}\right)^{-2\cdot302585}$$

It will now be found that the differential co-efficient of log. V is

$$-a_1\left(1+\frac{t}{a}\right)^{-2\cdot302585}$$

The constant a for pressure at temperature 100° C. was found to be +·03580. The new constant a_1 for volume at the same temperature, will be found to be —·03265.

In the investigation of the law of pressure above referred to, it has been shown (*Philosophical Magazine*, vol. xxix., p. 179) that for any given interval of temperature, the logarithm of the pressure P of saturated steam is a simple function of the logarithm of the expansive force p, of a unit weight of a perfectly elastic vapor maintained at a constant volume. The quantity p being

$$= 1 + \frac{t}{a} = e^{t}{}_{1},$$

it was here shown that

$$\frac{d \cdot \log. \text{P}}{d \cdot \log. p} = a\, a\, p^{-n} = a\, a\, e^{-n t_1} = a\, a\, e^{\log. \text{P}}.$$

By integration was obtained for hyp. log. P,

$$\log. \text{P} = \frac{a\, a}{a} \left\{ 1 - e^{-n \log. p} \right\}.$$

If we put

$$\phi \log. p = \frac{a}{n} \left\{ 1 - e^{-n \log. p} \right\},$$

we get

$$\log. \text{P} = a \phi \log. p, \text{ and } \text{P} = e^{a \phi^{\log. \text{P}}}.$$

The formula for the pressure of saturated steam being $\text{P} = e^{a \varphi^{\log. \text{P}}}$, the formula for volume is $\text{V} = e - a_1 \varphi_{\log. \text{P}}$; and the formula for the expansive force of a unit weight of such steam is

$$\text{P V} = e\,(a - a_{/})\, \phi^{\log. \text{P}} = e\, a_{//}\, \phi^{\log. \text{P}}.$$

The value of a in the formula for pressure has been shown to be ·03580, which represents the rate of increase per degree (Centigrade) of the pressure at the absolute temperature 376°, or at 100° on the Centigrade scale. In order to represent the law of volume, we have to put (for the same temperature) $a_{/} = -\cdot 03365$; and to represent the law of expansive force we have to put $a_{//} = +\cdot 00215$. We thus obtain the following expressions for pressure, volume, and expansive force, reckoned from 100° Centigrade:

$$\text{P} = e^{a \phi^{\log. \text{P}}}, \text{ and } \log. \text{P} = +\cdot 03580\, \phi \log. p.$$

$$\text{V} = a - a_{/}\, \phi^{\log. \text{P}}, \text{ and } \log. \text{V} = -\cdot 03365\, \phi \log. p.$$

$$\text{P V} = e\, a_{//}\, \phi^{\log. \text{P}}, \text{ and } \log. \text{P V} = +\cdot 00215 \phi \log. p.$$

By the aid of the three foregoing equations, any one of the three quantities P, V, or P V may be expressed in terms of either of the other two quantities. In order to express V in terms of P, we obtain by dividing log. V by log. P

$$\frac{\log. \text{V}}{\log. \text{P}} = -\frac{a_1 \phi \log. p}{a \phi \log. p} = -\frac{a_1}{a} = -\frac{\cdot 03365}{\cdot 03580}$$

$$= -\frac{1}{1 \cdot 06389} = -\cdot 939944;$$

consequently,

$$\text{V} = -\text{P}^{\cdot 939944}$$

and

$$\text{P V} = \text{P} + \text{P}^{\cdot 060056}.$$

Similarly may be obtained

$$\text{P} = \text{V} - \text{V}^{1 \cdot 06389}$$

and

$$\text{P V} = \text{V} - \text{V}^{\cdot 06389}.$$

According to the notation herein used, the quantities P, V, and P V represent ratios of pressure, volume, and expansive force at absolute temperature $(a + t)$ to similar quantities at absolute temperature (a) degrees. That is to say, P, V, and P V are used to represent quantities usually represented by $\frac{P}{P_0}$, $\frac{V}{V_0}$, and $\frac{P\,V}{P_0\,V_0}$, the quantities P_0, V_0, and $P_0\,V_0$ being constants determined of, or assumed to be determined, by observation for the absolute temperature (a) degrees. The theoretical numbers contained in the four annexed tables have been obtained by adopting the absolute temperature 376° (corresponding to 100° C.) as the fixed point from which the variable (t) is measured. At this point $P_0 = 2116{\cdot}4$ lbs. to the square foot, as determined by observation. At the same temperature, $V_0 = 26{\cdot}36$ cubic feet occupied by 1 lb. weight of water when converted into steam. And at the same temperature, $P_0\,V_0 = 2116{\cdot}4 \times 2636 = 55788$ foot lbs. expansive force exerted by 1 lb. weight of saturated steam. These three constants P_0, V_0, and $(P\,V)_0$ may, however, be more conveniently denoted by the letters H, $H_{,}$, and $H_{,,}$.

In Table I. are exhibited the results of twenty out of the twenty-three

TABLE I.—Volumes of a unit weight of saturated steam at different temperatures, as deduced from the experiments of Messrs. Fairbairn and Tate, compared with the volumes given by the new formula and by Dr. Rankine's theory respectively.

Temperature.		Pressure of saturated steam according to Regnault.	Specific volume relative to water according to Fairbairn and Tate.	Volume of one pound weight according to			
Fahrenheit.	Centigrade.			Fairbairn and Tate	Differences.	New formula.	Rankine
°	°	Atmospheres.		Cub. ft.	Cub. ft.	Cub. ft.	Cub. ft.
136·8	58·2	·180	8275·3	132·56	— ·49	123·07	132·20
155·3	68·5	·288	5333·5	85·44	— ·39	85·05	85·10
159·4	70·8	·317	4920·2	78 82	— 1·19	77·53	77·64
170·9	77·2	·415	3722·3	59·63	+ ·56	60·19	60·16
171·5	77·5	·421	3715·1	59·51	— ·08	59·43	59·43
174·9	79·4	·455	3438·1	55·08	+ ·12	55·20	55·20
182·3	83·5	·537	3051·0	48·87	— 1·57	47·30	47·28
188·3	86·8	·611	2623·4	42·02	— ·17	41·85	41·81
198·8	92·7	·764	2149·5	34·43	— ·50	33·93	33·94
242·9	117·2	1·793	943·1	15·11	+ ·12	15·23	15·25*
244·8	118·2	1·855	908·0	14·55	+ ·20	14·75	14·77
245·2	118·5	1·869	892·5	14·30	+ ·34	14·64	14·67
255·5	124·2	2·238	759·4	12·17	+ ·19	12·36	12·39
263·1	128·4	2·548	649·2	10·40	+ ·54	10·64	10·96
267·2	130·7	2·728	635·3	10·18	+ ·08	10·26	10·29
269·2	131·8	2·819	605·7	9·70	+ ·25	9·95	9·98
274·8	134·9	3·017	584·4	9·36	— ·22	9·14	9·16
282·6	139·2	3·500	497·2	7·96	+ ·16	8·12	8·14
237·2	141·8	3·767	458·3	7·34	+ ·24	7·58	7·60
292·5	144·7	4·086	433·1	6·94	+ ·08	7·02	7·04

* Instead of 15·61, stated in error by Dr. Rankine.

experiments on the density of saturated steam made by Messrs. Fairbairn and Tate. Three of the experiments made at high pressure and numbered 9′, 10′, and 14′, respectively, have been excluded because the particulars given of these experiments show them to have been defective. Nine of the selected observations were made for temperatures below 100° C. In the last column of this table are given, for purposes of comparison, the densities of saturated steam at corresponding temperatures according to Professor Rankine's theoretical tables, as stated by himself in a paper communicated to the Royal Society of Edinburgh in the year 1860. In that paper Professor Rankine expresses his opinion that the results of the experiments of Messrs. Fairbairn and Tate are in near accordance with his own theoretical tables at all temperatures. He adds, however, that at temperatures above 100° C., the aggregate of experiments indicates an excess of density above the theoretical density. This excess he states to amount on a average to ·27 parts of a cubic foot, being the difference between the experimental and theoretical volumes occupied by 1 lb. weight of saturated steam. It will be found on reference to the column of differences in the table annexed, that the above discrepancy has been reduced to one-fifth part of a cubic foot. This has been effected by excluding the three defective experiments mentioned, and by correcting an erroneous number given by Professor Rankine.

In the year 1850 M. Clausius published a formula, by means of which the density of saturated steam may now be calculated. This formula is given in the *Philosophical Magazine* for August, 1851, at page 107. It contains two quantities which are superfluous, as they are not found in the new formula above given. Nevertheless, the results yielded by M. Clausius' formula for volume are nearly identical with the results of the new formula for volume. M. Clausius deduced his formula from a theory of the moving force of heat originating with M. Carnot in 1824, and improved by M. Clapeyron in 1834.

The formula of M. Clausius is an expression for the latent heat of saturated steam relative to water (L), in terms of Joule's mechanical equivalent for a unit of heat (J), absolute temperature $(a + t)$, excess of volume of a unit weight of saturated steam above volume of same weight of water $(\mathrm{V} - v)$, and the differential co-efficient $\frac{d\,\mathrm{P}}{d\,t}$. If v be omitted as insignificant and within the errors of observation, the formula of M. Clausius may be written thus:

$$\mathrm{L} = \frac{1}{\mathrm{J}}(a+t)\,\mathrm{V}\frac{d\,\mathrm{P}}{d\,t}.$$

The value of $\frac{d\,\mathrm{P}}{d\,t}$ obtained from the new formula for pressure has been shown to be

$$\mathrm{P}_a\left(1+\frac{t}{a}\right)^{-(n+1)}$$

If this value be substituted in the formula of Clausius, we shall have

$$\text{L} = \frac{1}{\text{J}}(a+t)\,\text{V} \times \text{P}\,a\left(1+\frac{t}{a}\right)^{-(n+1)} = \frac{1}{\text{J}}\,a\,a\,\text{P}\,\text{V}\left(1+\frac{t}{a}\right)^{-n}$$

$$\text{L} = \frac{1}{\text{J}}\,a\,a\,\text{P}\,\text{V}\,p^{-n}$$

In the preceding equation the variables L and P V represent ratios to constants L_0 and $\text{P}_0\,\text{V}_0$. The actual latent heat is represented by $\text{L} \times \text{L}_0$, and the actual expansive force by $\text{P}\,\text{V} \times \text{P}_0\,\text{V}_0$. On substitution of these values in this equation, we get

$$\text{L} \times \text{L}_0 = \frac{1}{\text{J}} \cdot a\,a\,\text{P}\,\text{V} \times \text{P}_0\,\text{V}_0\,p^{-n}$$

or, separating variables from constants, we have

$$\text{L} = \frac{1}{\text{J}} \cdot \frac{a\,a\,\text{P}_0\,\text{V}_0}{\text{L}_0}\,\text{P}\,\text{V}\,p^{-n}$$

If $t = 0$, we have

$$\text{P}\,\text{V} = 1,\ p^{-n} = 1,\ \text{and}\ \text{L}_0 = 1;$$

consequently,

$$1 = \frac{1}{\text{J}} \cdot \frac{a\,a\,\text{P}_0\,\text{V}_0}{\text{L}_0} \text{ or } \text{J} = \frac{a\,a\,\text{P}_0\,\text{V}_0}{\text{L}};$$

that is,

$$\text{J} = \frac{\cdot 0358 \times 376 \times 2116{\cdot}4 \times 26{\cdot}36}{536{\cdot}5} = 1399{\cdot}7.$$

The quantity J, whose value has thus been determined to be 1399·7, is the mechanical equivalent in foot-pounds of a Centigrade unit of heat, the corresponding equivalent for a Fahrenheit unit of heat being 777 foot-pounds. The value of such mechanical equivalent, as determined by Dr. Joule, is 1389·6 for a Centigrade unit, or 772 for a Fahrenheit unit of heat. If the constant V_0 be assumed to represent 26·17 cubic feet instead of 26·36 cubic feet, the resulting value of J will be identical with the value adopted by Dr. Joule himself.

It having been found that

$$\text{L} = \frac{1}{\text{J}}\,\frac{a\,a\,\text{P}_0\,\text{V}_0}{\text{L}_0}\,\text{P}\,\text{V}\,p^{-n} \text{ and } \text{J} = \frac{a\,a\,\text{P}_0\,\text{V}_0}{\text{L}_0},$$

it follows that

$$\text{L} = \text{P}\,\text{V}\,p^{-n}$$

an equation which represents the corresponding values of L and P V, when the latent heat, as well as the expansive force at the absolute temperature a, whence t is measured, are taken equal to unity.

By means of the last equation and the formula for P V in terms of log. p, the latent heat may be expressed in terms of the differential coefficient of the expansive force P V. The formula gives on differentiation,

$$\frac{d.\log.\text{P}\,\text{V}}{d.\log.p} = a_{11}\,a\,p^{-n} \text{ or } \text{P}\,\text{V}\,\frac{d.\log.\text{P}\,\text{V}}{d.\log.p} = a_{11}\,a\,\text{P}\,\text{V}\,p^{-n};$$

consequently, since

$$\frac{d.\,\text{P V}}{\text{P V}} = d \log.\ \text{P V} \text{ and } \text{L} = \text{P V} p^{-n}$$

$$\frac{d.\,\text{P V}}{d.\log.p} = a_{11}\, a\, \text{P V} p^{-n} = a_{11}\, a\, \text{L} = 80140\ \text{L};$$

that is, the latent heat of saturated steam (relative to water at the same temperature) is equal to the differential co-efficient of the expansive force P V, divided by $a_{11}\, a$ (= ·80840).

By means of the differential co-efficient of log. P V above given, we may find the temperature at which d . log. P V becomes equal to d . log. p; that is, the temperature at which the rate of increment of the expansive force of a unit weight of saturated steam is equal to the rate of increment

TABLE II.—Volumes occupied by a unit weight of saturated steam at different temperatures, according to the new formula, the formula of M. Clausius, and the formula of Dr. Rankine, respectively.

Temperature.			V.	V × H_1.		
			Relative volume according to new formula.	Volume of one pound weight of saturated steam according to		
Fahrenheit.	Centigrade.	Absolute.		New formula.	Clausius.	Rankine.
°	°	°		Cubic feet.	Cubic feet.	Cubic feet.
32	0	276	12360	3258	3350	3390
50	10	286	6400	1687	1722	1732
68	20	296	3486	919·0	932·7	934·6
86	30	306	1988	524·0	529·5	529·2
104	40	316	1180	311·2	313·4	312·8
122	50	326	727·2	191·8	192·5	192·0
140	60	336	463·0	122·1	122·4	122·0
158	70	346	303·8	80·08	80·18	80·02
176	80	356	204·8	53·98	54·01	53·92
194	90	366	141·5	37·80	37·30	37·26
212	100	376	100·0	26·36	26·36	26·36
230	110	386	72·15	19·02	19·02	19·03
248	120	396	53·04	13·98	13·98	14·00
266	130	406	39·68	10·46	10·46	10.48
284	140	416	30·17	7·95	7·96	7·97
302	150	426	23·27	6·14	6·14	6·15
320	160	436	18·20	4·80	4·80	4·82
338	170	446	14·42	3·80	3·80	3·81
356	180	456	11·55	3·05	3·05	3·06
374	190	466	9·360	2·47	2·47	2·48
392	200	476	7·661	2·02	2·02	2·02
410	210	486	6·330	1·67	1·67	1·67
428	220	496	5·276	1·39	1·38	1·39
446	230	506	4·434	1·17	1·16	{ (not stated)

of expansive force of a unit weight of a perfectly elastic gas maintained at a constant volume. Since

TABLE III.—The expansive force of a unit weight of saturated steam at different temperatures, according to three different formulas, compared with the expansive force of a unit weight of a perfectly elastic gas maintained at a perfect volume.

Temperature.		$p = 1 \pm \frac{t}{a}$	P V.		P H × H$_{,,}$	
Centigrade.	Absolute.	Relative expansive force of a unit weight of a perfectly elastic vapor occupying a constant volume.	Relative expansive force of a unit weight of saturated steam.		Absolute expansive force of one pound weight of saturated steam.	
			New formula.	Clausius.	New formula.	Rankine.
°	°				Ft. lbs.	Ft. lbs.
0	273	·7340	·7351	·7557	41008	41589
10	286	·7606	·7966	·7824	42769	43170
20	296	·7872	·7970	·8088	44461	44730
30	306	·8138	·8261	·8348	46085	46250
40	316	·8404	·8541	·8601	47646	47720
50	326	·8670	·8809	·8847	49145	49160
60	336	·8936	·9067	·9091	50583	50560
70	346	·9202	·9315	·9326	51964	51940
80	356	·9468	·9552	·9558	53291	53250
90	366	·9734	·9781	·9781	54564	54520
100	376	1·0000	1·0000	1·0000	55788	55788
110	386	1·0266	1·0211	1·0211	56964	56960
120	396	1·0532	1·0414	1·0415	58095	58130
130	406	1·0798	1·0608	1·0611	59182	59240
140	416	1·1064	1·0796	1·0801	60228	60300
150	426	1·1330	1·0976	1·0981	61235	61320
160	436	1·1596	1·1150	1·1157	62204	62330
170	446	1·1862	1·1317	1·1319	63138	63260
180	456	1·2127	1·1479	1·1479	64037	64180
190	466	1·2393	1·1634	1·1625	64904	65040
200	476	1·2660	1·1784	1·1766	65740	65860
210	486	1·2926	1·1928	1·1894	66546	66670
220	496	1·3191	1·2068	1·2016	67236	67470
230	506	1·3457	1·2203	1·2126	68077	(not stated)

$$\frac{d\,.\,\log.\,\text{P V}}{d\,.\,\log.\,p} = a_{11}\,a\,p^{-n} = \cdot 80840\left(1+\frac{t}{376}\right)^{-1\cdot 302585}$$

we shall have $d\,.\,\log.\,\text{P V} = d\,.\,\log.\,p$, when

$$\left(1+\frac{t}{376}\right)^{-1\cdot 302585} = \cdot 80840.$$

The value of t, which satisfies the above equation, is negative, and equals $-56°$. Consequently, the absolute temperature at which $d\,.\,\log.\,\text{P V} = d\,.\,\log.\,p$ is $(376 - 57)$ or $320°$, which corresponds to $(320 - 276)$ or $44°$ of the Centigrade thermometer. The ratio $\frac{d\,.\,\log.\,\text{P V}}{d\,.\,\log.\,p}$ is less than unity for all temperatures above $44°$ C., and greater than unity for all temperatures below that point.

In Tables II. and III. the values at different temperatures of v and p v, given by the new formulas, are compared with similar values obtained from the published tables of Professor Rankine, and with similar values obtained from the formula for volume by M. Clausius, in combination with the new formula for pressure of saturated steam. On comparing together the three series of results, it will be perceived that for all temperatures above 60° C., the three series of results may be said to be identical with one another. At temperatures below 60° C., the two series of M. Clausius and Professor Rankine continue to agree with one another, but they disagree slightly with the results of the new formula. This disagreement arises from the circumstance, that the first two series of results are regulated by the law of latent heat adopted by M. Regnault, which law is in complete accordance with the formula $L = p\,v\,p^{-n}$ for all temperatures above 60° C., whilst it deviates slightly from such formulas for all lower temperatures.

In Table IV. will be seen, for various intervals of temperatures from 0° C. to 220 C., the relation between the numbers for latent heat given by M. Regnault, and the true numbers for latent heat which flow from

TABLE IV.—The latent heat of saturated steam according to M. Regnault, compared with the latent heat deduced from the formula of M. Clausius, which is $L = \frac{1}{J}(a+t)\,v\,\frac{dp}{dt} = p\,v\,p^{-n} \times$ by a constant.

Temperature.		$\left(\frac{1}{2}+\sqrt{\frac{1}{4}+\frac{1}{p^n}}\right)^n$	p v.	L.	$L \times L_0$.	Latent heat, (Regnault.)	Differences.
Centigrade.	Absolute.			$p\,v\,p^{-n}$	$p\,v\,p^{-n} \times 636{\cdot}5$.		
					Units of heat.	Units of heat.	Units of heat.
°	°						
0	276	1·4959	·7351	1·0996	589·9	606·5	— 16·6
20	296	1·3656	·7970	1·0883	583·9	592·6	8·7
40	316	1·2541	·8541	1·0711	574·7	578·7	4·0
60	336	1·1478	·9067	1·0498	563·2	564·7	1·5
80	356	1·0738	·9552	1·0257	550·6	550·6	·3
100	376	1·0000	1·0000	1·0000	536·5	536·5	·0
120	396	·9347	1·0414	·9734	522·2	522·3	·1
140	416	·8766	1·0796	·9464	507·7	508·0	·3
160	436	·4246	1·1150	·9195	493·3	493·6	·3
180	456	·7778	1·1479	·8928	479·0	479·0	·0
200	476	·7355	1·1784	·8667	465·0	465·0	+ ·7
220	496	·6971	1·2068	·8413	451·4	449·4	2·0

the adoption of M. Clausius' formula for volume, in combination with the new formula for pressure of saturated steam. It will be seen that for all temperatures above 60° C. there is no appreciable difference between experimental and theoretical numbers. At temperatures below 60° C. there is a slight discrepancy between the alleged experi-

mental numbers and the theoretical numbers. On a reference, however, to the account given by M. Regnault of the various unsatisfactory experiments which he has made for temperatures below 60° C., there will be found no ground for believing that the new law for latent heat, (expressed by the equation $L = P V p^{-n}$,) which is indisputably true for all temperatures above 60° C., is not also true for all lower temperatures. (See *Mémoires de l'Académie*, vol. xxi., pp. 712 and 722.)

The latent heat of saturated steam adopted by M. Regnault is deduced from a well known empirical law propounded by him, as affording a near representation of the total heat absorbed by a unit weight of saturated steam during its conversion from water and its elevation in temperature from 0° C. to t° Centigrade. The total heat is called λ, and the formula is

$$\lambda = 606{\cdot}5 + {\cdot}305\,t,$$

this quantity representing units of heat for temperature measured by the Centigrade thermometer, and a unit of heat representing the quantity of heat absorbed by a unit weight of water on elevation of its temperature from 0° C. to 1° Centigrade. The latent heat is obtained by subtracting from the "total heat" (λ) the number of units of heat absorbed by a unit weight of water whilst its temperature is being raised from 0° C. to t° Centigrade. For example, if $t = 200$° C., then we have

$$\lambda = 606{\cdot}5 + {\cdot}305 \times 200 = 667{\cdot}5.$$

From this number is to be deducted the heat absorbed by a unit weight of water whilst its temperature is being elevated from 0° to 200° C. This is 200 units of heat, together with 3·2 units addition made for increased specific heat or capacity of water at 200° C. We have, consequently, the resultant latent heat of saturated steam at 200° C. = 667·5 — 203·2 = 464·3 units of heat, which is the number adopted by M. Regnault, as stated in the last page of vol. xxi. of the *Mémoires de l'Académie*, &c.

The lowest average temperature at which observations on latent heat were made by M. Regnault was + 10° C. At this point the latent heat observed is stated to have been 599·5, whilst the new formula would give 587·4 Centigrade units of heat. The difference 12·1, which is the maximum difference between theory and a selected series of experiments. M. Regnault remarks that the difficulties are great in obtaining results to be relied upon from observations on latent heat of saturated steam made at temperatures below 60° C., or at pressure less than one-fifth of an atmosphere. He says that he has tried various methods of observation at these low temperatures. He assigns no reason for the preference given to the method of observation finally adopted, and he expresses no confidence in the results which he adopts. In speaking of the "total heat" adopted for the lowest temperature observed, + 10° C., M. Regnault says that he "believes that it will be found not very far from the truth."

M. Regnault's table of latent heat is mainly dependent on his em-

pirical law for "total heat" expressed by the formula $A + Bt$. This law is of extreme simplicity, and for that reason the chances are very much against its being true for the entire range of temperature from 220° C. to 0° C., to which M. Regnault tries to make it apply. That it should be found to be true from 220° C. to 60° C., is something extraordinary, and ought to satisfy all reasonable expectation. There is, however, a good reason for anticipating failure in this empirical law when extended to low temperatures. The point of temperature where the suspected failure occurs is not very distant from a remarkable point of temperature (44° C.) indicated (as already stated) by new formula by P V, where d . log. P V $= d$. log. p. It is highly improbably that an empirical law so simple as $A + Bt$ should indicate correctly the "total heat" for ranges of temperature *below* this remarkable point (44° C.) as well as for ranges of temperature *above* this point.

On the Adhesion of Locomotive Engines and Certain Expedients for Increasing or Supplementing that Function.* By VAUGHAN PENDRED, C.E.

From the London Mechanics' Magazine, November, 1865.

The following is an abstract of a paper upon the above subject which was read before the Society of Engineers on Monday evening last: The author commenced by pointing out that the subject of the paper was one of the most important connected with the locomotive, but that very little precise information existed respecting it. He then proceeded to show that the motion of the engine was not alone due to the thrust of the crank-shaft on the brasses, but also directly to the pressure of the steam on the cylinder lids. He then considered at some length the theories of friction, pointing out the anomalies which exist between them and the laws of adhesion as determined by Bochet. The author continued: It would appear that if adhesion is to be relegated to the domains of friction at all, it must be classed under the head of static friction, or, as it is sometimes called, the friction of repose. When one surface rests upon another with any appreciable weight or pressure, we know that a peculiar resistance, assumed to be distinct from that due to *vis inertia*, will be encountered if we attempt to slide one surface over the other. There is some little difficulty met with in conducting such investigations, as it is not easy, although quite possible, to avoid confounding the resistance due to inertia with that of statical friction, and for this reason, perhaps, the results obtained by different experiments manifest considerable discrepancies. As matters stand, we are told upon the one hand by Morin, Rennie, and most other writers on the subject: 1st. That the co-efficient of the friction of repose is greater in all cases than that of the friction of motion. 2d. That when no lubricant is interposed, the friction of any two sur-

* It is the intention of the author of this paper to publish it *in extenso*.

faces (whether quiescent or in motion) is directly proportional to the force with which they are pressed together; that is to say, a double pressure gives double friction, triple pressure, triple friction, and so on. 3d. That when no lubricant is interposed, the amount of the friction is in every case wholly independent of the extent of surfaces in contact. 4th. That the friction of motion is wholly independent of the velocity of the motion. Now, it so happens that it has been known in a rough way for some time that these conclusions are not borne out in locomotive practice. It is generally understood, for example, that the co-efficient of adhesion increases in a more rapid ratio than the weight. Indeed, I believe George Stephenson was the first to call attention to the fact. But the character as experimentalists and philosophers possessed by such men as Morin and Rennie, puts it out of the question that we should dispute the general accuracy of the conclusions at which they have arrived, as given above. We shall get over the difficulty by remembering that all their experiments were confined to cases in which the surfaces did not sensibly cut into or abrade each other—to pressures less, indeed, than 500 lbs. or 600 lbs. per inch; and it is, therefore, quite possible that they may be strictly accurate in their deductions as far as these went, while another series of experiments, commencing where they left off, and including great pressures, would give very different results.

The only really valuable investigation of this kind, of the existence of which I am aware, is that to which I have already alluded as having been conducted by M. Bochet, and this finds its true value in the fact that it was carried out under such conditions as obtain in every-day railway practice. M. Bochet's experiments were conducted upon cases of sliding friction only, at all velocities between 0 and 27 yards per second, or about 56 miles per hour. They were made with various materials, iron of different degrees of polish, woods, hard and soft, wet and dry, resinous and not resinous, on leather and gutta-percha, and with contact surfaces of very different dimensions. In all cases the frictional surfaces appear to have been dragged under the known weights of certain railway wagons, over the surfaces of the rails in various states, wet, dry, rough, oiled, polished. We have not time to go into the details of these experiments. I can only refer those desiring minute information to M. Bochet's memoirs addressed to the Academy of Sciences of Paris. The results, however, are very remarkable. They have been printed in a very condensed form in one of our scientific periodicals; sufficiently at length, however, to answer our purpose, and I cannot do better than give them to you as they stand in the pages of the *Practical Mechanics' Journal.*

"1st. Friction, under conditions apparently perfectly identical, is never precisely alike, so that its amount cannot be represented by a well defined curved line, but by a zone through which a mean curve may be regarded as the nearest co-efficient. 2d. Friction diminishes with the velocity, other things being equal. 3d. Friction varies with the surface rubbed, other things being equal, or (and this is very important) with the specific pressure. The limits are very small when

the pressure and velocity are small, but become sensible when either is great." M. Bochet's fourth statement apparently conflicts with the every-day experiences of locomotive engine-drivers. It is simply that with iron on iron rails, the friction is the same whether the rails be dry, moist, or even greased. "5th. The state of polish powerfully affects the friction of iron on iron. 6th. There is no special increase of friction on starting from rest to motion, except for wood or leather on moist or greased rails. With iron on iron rails, dry, moist, or greased, the statical friction is precisely the same as the friction of motion while the velocity is low. The statical friction is greater, however, at high velocities."

There are three physical conditions, viz: molecular attraction, roughness of surface, and speciality of abrasion in rubbing, which, acting more or less together, appear to M. Bochet sufficient to account for all his observed facts. He assumes the co-efficient of adhesion to amount, in the case of smooth, bright wheels on rails in the same condition, to at most from ·3 to ·2, less a third very small co-efficient, depending on the quality of the metal, so to speak, and variable circumstances impossible to reduce to a general law. In other words, the co-efficient of no two wheels, no matter how apparently identical, will be precisely the same. For ordinary circumstances, wherein the rails are neither very brightly polished nor very smooth, M. Bochet gives the co-efficient of adhesion as varying from ·4 to ·25. It is unnecessary that I should enter into any consideration of the numerous results which he has obtained from experiments with other substances than iron.

The author then proceeded to consider the extent of areal contact surface, and detailed certain experiments made with a view to determine its amount in the case of engines, with drivers varying from 5 feet to 6 feet 6 inches in diameter, carrying loads of 5 tons to 5·5 tons each, and fitted for the most part with steel tires, if not quite new at least in fair order. The method pursued was very simple. A part of the rail being well cleaned, the engine was brought over this spot, and two thin strips of thin, stiff paper, or, better still, thin rolled sheet iron, $\frac{1}{1000}$ inch thick, were placed on the rail, one in advance and the other in the rear of the vertical line descending from the axle through the point of contact. These slips were then brought as closely together as the wheels would permit; that is to say, they were, so to speak, wedged under the tire until the space between this last and the rail became so narrow that metal or paper could go no further. The distance between the nearest edges was then measured, and was taken to represent the length of the area of contact with the rail approximately. Samuelson used gold leaf just as the author used sheet iron and paper. Now, it must be remembered, that so long as as the tire is removed from the rail by even the thickness of a sheet of paper, no contact exists; and it is also clear that the curve of the tire near the point of contact and the surface of the rail very closely approximate to the condition of parallel lines; in other words, the curve of the tire and the line of the rail subtend so small an angle, that we are justified

in considering that a considerable deduction may be made from the length of contact surface, as given by these experiments. Now, the mean of six distinct experiments carefully enough conducted gave the distance at $1\frac{3}{8}$ inch. It is true that in one other instance the distance was as great as $2\frac{3}{4}$ inches, but this occurred with a tire a good deal worn, and so it happened that the part just beneath the balance weight within the rim was the place selected to rest on the rail, and here a flat existed, due possibly to the well known influence of the weight when in rotation. After making every allowance and deduction, we may safely assume that, with a good rail well supported, and steel tires in fair order, the contact surface does not measure more than 1 inch in length, while its breadth may average $1\frac{3}{4}$ inch, say 2 inches. These numbers multiplied into each other give us a superficial area of contact of two square inches. The loads, therefore, must in practice exceed 2·5 tons per square inch as a rule. They considerably exceeded 1 ton, and were, therefore, in excess of the pressures experimented upon by Morin, Rennie, &c., and the foregoing data fully bear out the assertion. Furthermore, the pressure over the entire contact area is not constant; it rises from nothing towards the edges to a maximum near the centre of the area, where doubtless pressures equivalent to five and six tons to the inch may exist.

The value of the co-efficient of adhesion was then considered by the author, which in his opinion was usually underestimated. In proof of this opinion he adduced several illustrations selected from the performances of engines both here and abroad. After noticing at some length the various schemes which have been advanced from time to time for increasing adhesion, such as Blenkinsopp's rack rail and Brunton's feet, &c., he came to the consideration of more modern improvements in this direction. To follow the author; Up to the year 1835 rack rails and mechanical feet were the popular devices for overcoming the difficulty, to which we may, perhaps, add Chapman's chain, which, after all, is but a modification of the rack. After a time it came to be understood that smooth tired wheels and smooth rails could alone meet the mechanical exigencies of the railway system, and to Messrs. C. B. Vignoles and John Ericsson must be attributed the honor of first practically reconciling the conditions—smoothness of gripping surface with increase of adhesion. Their patent was taken out as far back as the year 1830, but it received little or no attention at the time, possibly because racks and feet held full possession of all the favor which could be spared from the smooth tire. Indeed, until the date of the trials with Mr. Fell's locomotive at Whalley Bridge, very few engineers knew anything whatever of the invention by Messrs. Ericsson and Vignoles of the only system which, at the present moment. holds out a prospect of enabling locomotives to work gradients of more than 1 in 20 with economy and certainty. A very few words will explain the whole principle. The adhesion of a locomotive is a result of the forcible contact of its wheels with the rails, the force being due to the weight of the machine. Adhesion, therefore, is so far limited by the

weight of the engine. But it is obvious that a wheel may be forced against a rail by other agencies as well as mere weight. Thus, a central rail being provided, two horizontal wheels may be made to grip it between them, precisely as the rolls of an iron mill seize a bar; and if these wheels are pressed together with sufficient force, and are caused to revolve, the engine will be compelled to move forward; and this pressure may be quite independent of the weight of the machine. In Messrs. Vignoles and Ericsson's engine the central rail is gripped between two horizontal wheels. On the upper end of the shaft of the larger of these is fitted a bevel wheel, taking into another bevel wheel on the crank-shaft. A beam is affixed to the frame of the engine; it carries the bearings of the gripping wheels. Those of one, the smaller of the two, are fitted with a species of lever arrangement easily understood, by which it was to be forced against the rail, in order that the adhesion of the larger wheel might be called into play. The inventors proposed to employ manual power, which would be obviously insufficient for the required purpose. This fact, of course, does not affect the general principle. The author continued: Mr. Fell had taken out a patent early in 1863 for the use of the mid-rail, somewhat as proposed by Vignoles and Ericsson. In saying this I do not wish to detract from Mr. Fell's originality. Indeed, I think it very possible that, considering the obscurity enwrapping the inventions of both Ericsson and Sellers, he believed himself to be the true and original inventor of the scheme. Shortly after he secured his patent, the subject was taken up warmly by Mr. Brassey, and Mr. Alexander, of the Canada Works, Birkenhead, was consulted on the practicability of constructing an engine on Mr. Fell's system. The result was that an order was given for the building of an engine without delay. In fact, every other consideration save promptitude was put on one side, and, as often happens in those cases, no time was left for working out the designs. Mr. Alexander took the matter in hand, and an engine was built. This engine weighs, loaded, 14 tons 10 cwt., the boiler is 7 feet 9½ inches long, and 2 feet 9 inches in diameter. It is fitted with 100 tubes, 1½ inch diameter, externally. There is a heating surface of 420 square feet and a grate area of 6 feet 6 inches. It will be seen that the engine has four cylinders, two outside, 11¾ inches diameter, with 18 inches stroke, working four coupled vertical wheels, on which the entire weight of the machine is supported, 2 feet 3 inches in diameter. There is nothing remarkable in any respect about this department of the machinery, and we may, therefore, dismiss it without further notice. Beneath the centre line of the boiler, and at considerably higher level than the outside cylinders, two others, 11 inches in diameter and 10 inches stroke, are fixed, facing each other. The valve chests are placed below the cylinders, and the valves are put in motion by a link much the same as that ordinarily used, except that it is curved the reverse way, although movable, because the eccentrics are not both on the same shaft. Below the carriage are fitted eight axle boxes carrying four vertical shafts of great strength. On the upper ends of each of these is keyed a crank. The pins of these cranks are laid hold of by

rods coupling them in pairs. On the lower ends of the shafts are keyed four horizontal driving wheels, 1 foot 4 inches in diameter, which, as arranged, grip between them the mid-rail. This rail is the ordinary double-headed variety, bolted to suitable sleepers. The eccentrics for working the valve of the leading cylinder are keyed one on each of the forward grip wheel shafts. Those for working the valve of the after cylinder are in like manner keyed one on each of the trailing shafts. A flat iron table is bolted to the frame to support each link. The links are provided with suitable bosses to slide on these tables. Reversing is simply effected in the usual way from the foot-plate. The eccentrics for the outside cylinders are keyed on the leading horizontal axle, as they could not be provided for elsewhere.

(To be continued.)

For the Journal of the Franklin Institute.

Moment of Inertia of Surfaces. By De Volson Wood, Prof. C.E., University of Michigan.

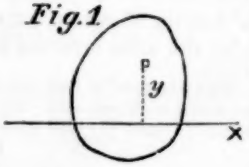
In the investigation of the resistance of beams or columns, the moment of inertia of the transverse sections plays a very important part. We may always deduce the moment of inertia of a surface from the well known expression $\iint y^2\,dy\,dx$; but we may often facilitate operations by deducing from it some general rules. It is my purpose in the following article to give a general discussion of the subject, and apply each principle in the development to the solution of a problem.

General Expression.

The moment of inertia of a surface is the sum of the products found by multiplying each elementary area by the square of its distance from any assumed axis.

Let dA = an elementary area.
y = its distance from the axis.
and I = the moment of inertia of the surface.

Fig. 1



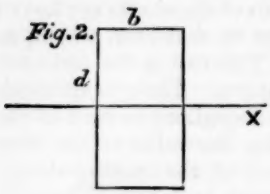
Then, according to the definition,
y^2dA = the moment of inertia of an element,

and $$I = \int y^2 dA, \qquad . \quad . \quad . \quad (1.)$$

Let the surface be referred to rectangular co-ordinates. Then $dA = dy\,dx$;

$$\therefore I = \iint y^2\,dy\,dx, \qquad . \quad . \quad . \quad . \quad (2.)$$

Fig.2.



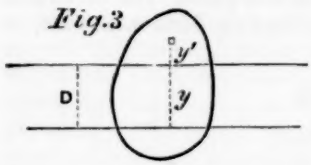
EXAMPLE.—To find the moment of inertia of a rectangle about an axis passing through the centre and parallel to the ends.

Let b = the breadth, d = the depth; then we have

$$I = \int_0^b \int_{-\frac{1}{2}d}^{+\frac{1}{2}d} y^2\, dy\, dx = \frac{1}{12} d^3 \int_0^b dx = \frac{1}{12} bd^3 \quad (3.)$$

FORMULA OF REDUCTION.

Fig.3



To find the relation between the moments of inertia about two parallel axes, one of which passes through the centre of gravity.

Let D = the distance between them.

y^1 = the ordinate from the axis which passes through the centre.

Let y = the ordinate from the other axis.

I^1 = the moment of inertia about the axis through the centre.

We have $y = D + y^1$; hence (1) becomes

$$\int y^2\, dA = \int y^{1^2} dA + \int 2D\, y^1\, dA + D^2 \int dA.$$

But, because x^1 passes through the centre, we have $2D \int y^1\, dA = 0$,

when it is integrated so as to include the whole area, and $\int dA = A$;

hence, we find

$$\int y^2\, dA = \int y^{1^2}\, dA + D^2 A.$$

$$\text{or } I = I^1 + D^2 A, \quad . \quad . \quad . \quad (4.)$$

This is called the *formula of reduction*, and may thus be enunciated: The moment of inertia of a surface about any axis, equals the moment of inertia about an axis parallel to it which passes through the centre, *plus* the area into the square of the distance between them.

EXAMPLE.—To find the moment of inertia of a rectangle about an axis which coincides with one end. The distance between the axes will be $\frac{1}{2}d = D$, and $A = bd$; hence, (4) and (3) will give

$$I = \frac{1}{12} bd^3 + \tfrac{1}{4} d^2.\ bd = \tfrac{1}{3} bd^3, \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

From (4) we find

$$I^1 = I - D^2 A, \quad . \quad . \quad . \quad . \quad (6,)$$

which is sometimes very convenient.

For instance, it is easier to find the moment of inertia of a triangle, about an axis which passes through its apex, and parallel to the base, than about any other axis; but having found this, we may easily find it about an axis parallel to it which passes through the centre.

To illustrate,

Let b = the base, and
d = the altitude of the triangle.

Then, taking the origin at the vertex, and we have

$$x : y :: b : d \quad \therefore x = \frac{b}{d} y,$$

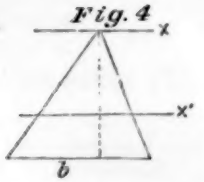


Fig. 4

and (2) becomes

$$I = \int_0^d y^2 x\, dy = \frac{b}{d} \int_0^d y^3 dy = \tfrac{1}{4} b d^3, \qquad (7.)$$

The area $= \frac{1}{2} bd = A$.

$D = \frac{2}{3} d$ = the distance from the vertex to the centre; hence, (6) becomes

$$I^1 = \tfrac{1}{4} bd^3 - \tfrac{1}{2} bd \times \frac{4}{9} d^2 = \frac{1}{36} bd^3, \quad . \quad . \quad . \quad . \quad . \quad . \quad (8.)$$

If the base be the axis, (8) and (4) give

$$I = \frac{1}{36} bd^3 + \tfrac{1}{2} bd \times \frac{1}{9} d^2 = \frac{1}{12} bd^3, \quad . \quad . \quad . \quad . \quad . \quad (9.)$$

Relation between Rectangular Axes.

We will now find the relation between the moments of inertia about the axes of two systems of rectangular co-ordinates, having the same origin, but inclined to each other.

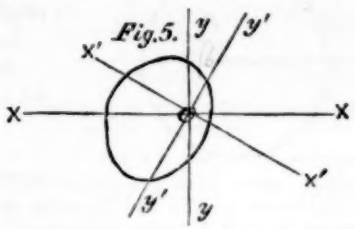


Fig. 5.

Let o, Fig. 5, be the origin, and

$$yoy^1 = xox^1 = \beta.$$

Also, I_x = the moment of inertia about xox.

I_y = the moment of inertia about yoy.

I_{x1} = the moment of inertia about x^1ox^1.

I_{y1} = the moment of inertia about y^1oy^1.

Then, by the definition, we have

$$I_x = \int y^2 dA, \qquad I_y = \int x^2 dA, \quad . \quad . \quad . \quad (10.)$$

$$I_{x1} = \int y^{1^2} dA, \qquad I_{y1} = \int x^{1^2} dA, \quad . \quad . \quad (11.)$$

For the transformation of rectangular co-ordinates, we have

$$\left.\begin{aligned} x^1 &= x \cos \beta - y \sin \beta \\ y^1 &= x \sin \beta + y \cos \beta \end{aligned}\right\} \quad . \quad . \quad . \quad (12).$$

Hence, we have

$$x^{1^2} + y^{1^2} = x^2 + y^2,$$

which is called an *isotropic function*, (from the Greek $I\sigma o\varsigma$, equal, and $\tau\rho o\pi\omega$, turning, *i.e.* the distance from the origin to any point is the same for all inclinations of the systems of co-ordinate axes.)

$$\text{Let } B = \int xy dA \text{ and } B^1 = \int x^1 y^1 dA, \quad . \quad . \quad . \quad . \quad (13.)$$

Then, by combining (10), (11), (12), and (13), we readily find the following equations:

$$\left.\begin{aligned} I_{x^1} &= I_x \cos^2\beta + I_y \sin^2\beta - 2B\cos\beta\sin\beta \\ I_{y^1} &= I_x \sin^2\beta + I_y \cos^2\beta + 2B\cos\beta\sin\beta \\ B^1 &= (I_x - I_y)\cos\beta\sin\beta + B(\cos^2\beta - \sin^2\beta) \end{aligned}\right\} \quad (14).$$

By adding the 1st and 2d of (14), we find

$$I_{x^1} + I_{y^1} = I_x + I_y, \quad . \quad . \quad . \quad (15,)$$

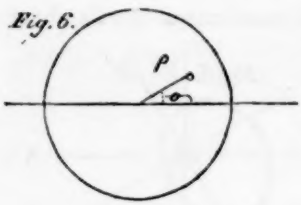
which is *isotropic;* and from which we see that *the sum of the moments of inertia about pairs of rectangular axes having the same origin is constant.*

From (10) and (15) we readily find that

$$I_x + I_y = I_{x^1} + I_{y^1} = \int (x^2 + y^2)\, dA = \int \rho^2 dA, \quad . \quad (16,)$$

in which $x^2 + y^2 = \rho^2 =$ a variable distance; and hence, from the definition, equation (16) is the moment of inertia about an axis perpendicular to the plane of the surface. This is called the *polar moment of inertia.* We see that it equals the sum of the moments about two rectangular axes which lie in the surface, and whose origin is on the polar axis.

Fig. 6.



Let $\theta =$ the variable angle; then will $\rho d\rho d\theta =$ an elementary polar area $= dA$; hence, (16) becomes

$$\iint \rho^3\, d\rho\, d\theta = I^p = \text{the } \textit{polar moment of inertia}, \quad . \quad . \quad (17.)$$

EXAMPLES.—1. To find the polar moment of inertia of a circle, about an axis passing through its centre, we have only to integrate (17) between the limits 0 and r for ρ, and 0 and 2π for θ; hence, we have

$$I_p = \int_0^{2\pi}\int_0^r \rho^3 d\rho d\theta = \tfrac{1}{2}\pi r^4, \quad . \quad . \quad . \quad . \quad . \quad (18.)$$

2. We may find in the same way that we found equation (3) that the moment of inertia of a rectangle about an axis passing through its centre and parallel to its sides, is $\frac{1}{12} b^3 d$; hence, the polar moment of a rectangle about an axis passing through its centre is, by equation (16),

$$I_p = \frac{1}{12} bd\,(b^2 + d^2) = \frac{1}{12} A\,(\text{diagonal})^2, \quad . \quad . \quad . \quad . \quad (19,)$$

that is, it equals one-twelfth the area multiplied by the square of the diagonal.

Knowing the polar moment, it is easy, in some cases, to find the moment about an axis in the surface.

For instance, if the moments about the rectangular axes are equal, equation (16) will give

$$2\int x^2\, dA = \int \rho^2\, dA;$$

$$\therefore I_x = \tfrac{1}{2} I_p, \quad . \quad . \quad . \quad . \quad . \quad (20.)$$

Hence, equations (20) and (18) give, for the moment of inertia of a circle, about an axis in the surface, and passing through the centre,

$$I = \tfrac{1}{4}\pi r^4, \quad . \quad . \quad . \quad . \quad (21,)$$

and, for the moment of a square about an axis in the surface, parallel to one side and passing through the centre, (20) and (19) will give

$$I = \frac{1}{24} b^2 (b^2 + b^2) = \frac{1}{12} b^4.$$

If the polar moment and one of the rectangular moments are known, the other rectangular moment may be easily found; for equation (16) gives—

$$I_y = I_p - I_x, \quad . \quad . \quad . \quad . \quad (21.)$$

MAXIMUM AND MINIMUM MOMENTS.

To find the position of the axes (for any assumed origin) which shall give a maximum moment about one axis and minimum about the other, we will suppose that I_x, I_y, and B, have been found for any assumed position of the axis.

By differentiating the first of (14), and placing it equal zero, we find

$$D_\beta = -2(I_x - I_y)\cos\beta \sin\beta + 2B(\sin^2\beta - \cos^2\beta) = 0;$$

$$\therefore \frac{-2B}{I_x - I_y} = \frac{2\cos\beta\sin\beta}{\sin^2\beta - \cos^2\beta} = \tan 2\beta, \quad . \quad (22.)$$

The second derivative, placed equal zero, gives $\tan 2\beta = \pm 1$; hence, of the two values of β found from (22), one will give the position of I_{x_1} for a maximum, and the other the position for a minimum.

Proceeding in a similar way with the second of (14), and we find that when I_{x_1} is a maximum, I_{y_1} is a minimum, and *vice versa*. Equation (22) in the third of (14) gives $B^1 = 0$.

Let β_1 be the value of β found by equation (22), and x_1 y_1 the corresponding axes, called *principal axes*.

$B^1 = B_1 = 0$, and (14) becomes

$$\left.\begin{aligned} I_{x_1} &= I_x \cos^2\beta_1 + I_y \sin^2\beta_1 - 2B\cos\beta_1\sin\beta_1 \\ I_{y_1} &= I_x \sin^2\beta_1 + I_y \cos^2\beta_1 + 2B\cos\beta_1\sin\beta_1 \\ 0 &= (I_x - I_y)\cos\beta_1\sin\beta_1 + B(\cos^2\beta_1 - \sin^2\beta_1) \end{aligned}\right\} \quad (23.)$$

By adding the 1st and 2d of (23), and then multiplying them together, using the 3d in the reduction, we find

$$I_{x_1} + I_{y_1} = I_x + I_y,$$

$$I_{x_1} I_{y_1} = I_x I_y - B^2,$$

$$\therefore I_{x_1} = \tfrac{1}{2}(I_x + I_y) + \sqrt{\tfrac{1}{4}(I_x - I_y)^2 + B^2};$$

$$I_{y_1} = \tfrac{1}{2}(I_x + I_y) - \sqrt{\tfrac{1}{4}(I_x - I_y)^2 + B^2},$$

by means of which the principal moments may be found without knowing β_1.

EXAMPLE.—To find the principal axes of a rectangle, origin at the centre. We have already found, equation (3), that

$I_x = \frac{1}{12} bd^3$, and $I_y = \frac{1}{12} bbd$; we also have

$$B = \int_{-\frac{1}{2}d}^{\frac{1}{2}d} \int_{-\frac{1}{2}b}^{\frac{1}{2}b} xy\, dy\, dx = (\tfrac{1}{4}d^2 - \tfrac{1}{4}d^2) \int_{-\frac{1}{2}b}^{\frac{1}{2}b} x\, dx = 0,$$

which in (22) gives $\beta = 0$, and these in (23) give

$$I_{x_1} = I_x = \tfrac{1}{12} bd^3$$
$$I_{y_1} = I_y = \tfrac{1}{12} b^3 d;$$

hence, those axes which are parallel to the sides and ends of the rectangle are *principal axes.*

Moments in Reference to any System of Rectangular Axes, the Principal Moments being known.

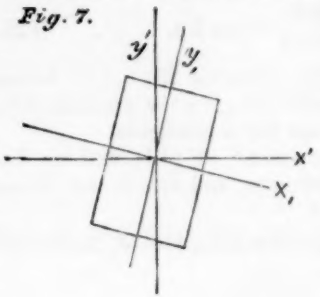
Suppose that the principal moments I_{x_1} and I_{y_1} are known, then we may easily find the moments about axes inclined at any angle; for we have only to make $I_x = I_{x_1}$, $I_y = I_{y_1}$, and $B = 0$ in (14). This done and we have

$$\left.\begin{aligned} I_{x^1} &= I_{x_1} \cos^2\beta + I_{y_1} \sin^2\beta \\ I_{y^1} &= I_{x_1} \sin^2\beta + I_{y_1} \cos^2\beta \\ B^1 &= (I_{x_1} - I_{y_1}) \cos\beta \sin\beta \end{aligned}\right\} \quad . \quad . \quad (24.)$$

If $I_{x_1} = I_{y_1}$, then $I_{x^1} = I_{y^1}$, and the figure may be said to have its moments of inertia perfectly *isotropic.* This is the case with the circle, regular polygons, and many other symmetrical figures.

Examples.—1. Take the case of a rectangle whose sides are inclined at a angle i with the axis of x^1. Then

Fig. 7.



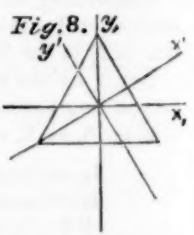
$\beta = 90° - i$, and (24) gives

$$I_{x^1} = I_{x_1} \sin^2 i + I_{y_1} \cos^2 i = \tfrac{1}{12} bd\,(d^2 \sin^2 i + b^2 \cos^2 i),$$
$$I_{y^1} = I_{x_1} \cos^2 i + I_{y_1} \sin^2 i = \tfrac{1}{12} bd\,(d^2 \cos^2 i + b^2 \sin^2 i).$$

If $d = b$, then $I_{x^1} = I_{y^1} = \tfrac{1}{12} d^4$, the same as before found.

2. Let the section be an equilateral triangle, with the axis of symmetry inclined at an angle i with the axis of x^1. Then $\beta = 90° - i$. We easily find that $I_{y_1} = \tfrac{1}{48} b^3 d$, and we have found $I_{x^1} = \tfrac{1}{96} bd^3$. See equation (8).

Fig. 8.



Hence, (24) becomes

$$I_{x^1} = \tfrac{1}{12} bd\,(\tfrac{1}{8} d^2 \sin^2 i + \tfrac{1}{4} b^2 \cos^2 i), \quad . \quad . \quad (25.)$$
$$I_{y^1} = \tfrac{1}{12} bd\,(\tfrac{1}{8} d^2 \cos^2 i + \tfrac{1}{4} b^2 \sin^2 i), \quad . \quad . \quad (26.)$$

Moment of Inertia of a Regular Polygon.

To find the moment of inertia of a regular polygon, let the axis of x pass through a vertex and the centre.

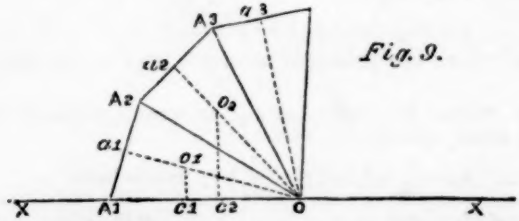


Fig. 9.

Let A_1, A_2, &c., Fig. 9, be the polygon; o its centre; o_1, o_2, &c., the centres of the triangles; oa_1, oa_2, &c., the altitudes.

Let $b = A_1A_2 = A_2A_3 = \&c.$

$d = oa_1 = oa_2 =$ the altitude.

$h_1 = o_1c_1$, $h_2 = o_2c_2$, &c.

$a = A_1oA_2 = A_2oA_3 = \&c. =$ angle at the vortex of each triangle.

$i_1 = a_1oA_1$, $i_2 = a_2oA_1$, &c., = the inclination of the axis of symmetry of each triangle to the axis of x.

k_1, k_2, k_3, &c., = the moment of inertia of the successive triangles about an axis passing through their centres and parallel to XOX.

I_1, I_2, I_3, &c., = the moments of inertia of the corresponding triangles about XOX.

$n =$ the number of sides in the polygon.

$a = \frac{1}{2}bd =$ the area of each triangle.

$A = na =$ the area of the polygon.

We have

$$a = \frac{360}{n} \qquad i_1 = \tfrac{1}{2}a \qquad h_1 = \tfrac{2}{3}d \sin i_1$$

$$b = 2a \tan \tfrac{1}{2}a \qquad i_2 = \tfrac{3}{2}a \qquad h_2 = \tfrac{2}{3}d \sin i_2$$

$$\cdot \quad \cdot \quad \cdot \qquad \cdot \quad \cdot \quad \cdot$$

$$i_n = \frac{2n-1}{2}a \qquad h_n = \tfrac{2}{3}d \sin i^n$$

By (25) we have

$$k_1 = \tfrac{1}{6}a\,(\tfrac{1}{3}d^2 \sin^2 i_1 + \tfrac{1}{4}b^2 \cos^2 i_1)$$
$$k_2 = \tfrac{1}{6}a\,(\tfrac{1}{3}d^2 \sin^2 i_2 + \tfrac{1}{4}b^2 \cos^2 i_2)$$
$$k_3 = \tfrac{1}{6}a\,(\tfrac{1}{3}d^2 \sin^2 i_3 + \tfrac{1}{4}b^2 \cos^2 i_3)$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$

$$k_n = \tfrac{1}{6}a\,(\tfrac{1}{3}d^2 \sin^2 i_n + \tfrac{1}{4}b^2 \cos^2 i_n)$$

By equation (4) we have

$$I_1 = k_1 + ah_1^2 = \tfrac{1}{2}a\,(d^2 \sin^2 i_1 + \tfrac{1}{12}b^2 \cos^2 i_1)$$
$$I_2 = k_2 + ah_2^2 = \tfrac{1}{2}a\,(d^2 \sin^2 i_2 + \tfrac{1}{12}b^2 \cos^2 i_2)$$
$$I_3 = k_3 + ah_3^2 = \tfrac{1}{2}a\,(d^2 \sin^2 i_3 + \tfrac{1}{12}b^2 \cos^2 i_3)$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$

$$I_n = k_n + ah_n^2 = \tfrac{1}{2}a\,(d^2 \sin^2 i_n + \tfrac{1}{12}b^2 \cos^2 i_n).$$

For any portion of the polygon we have

$$\Sigma I = \tfrac{1}{2}a\,(d^2 \Sigma \sin^2 i + \tfrac{1}{12}b^2 \Sigma \cos^2 i), \qquad . \quad . \quad (27,)$$

in which $\Sigma \sin^2 i = \sin^2 \frac{1}{2}a + \sin^2 \frac{3}{2}a + \sin^2 \frac{5}{2}a \ldots + \sin^2 \frac{2n-1}{2}a$

$$\Sigma \cos^2 i = \cos^2 \tfrac{1}{2}a + \cos^2 \tfrac{3}{2}a + \cos^2 \tfrac{5}{2}a \ldots + \cos^2 \frac{2n-1}{2}a$$

For the whole polygon $\Sigma \sin^2 i = \Sigma \cos^2 i$; hence, by adding the preceding expressions, we find

$$\Sigma \sin^2 i = \Sigma \cos^2 i = \tfrac{1}{2}n;$$

hence, for the whole polygon, equation (27) becomes

$$I = \tfrac{1}{4}A\,(d^2 + \tfrac{1}{12}b^2), \qquad . \quad . \quad . \quad (28.)$$

For the square, $d = \frac{1}{2}b$, $A = 2b^2$; $\therefore I = \frac{1}{12}b^4$.

For the hexagon, $d = \frac{1}{2}b \cot 30°$, $A = 3\,bd$; $\therefore I = 0{\cdot}96214\,d^4$.
For the octagon, $d = \frac{1}{2}b \cot 22\frac{1}{2}°$, $A = 4\,bd$; $\therefore I = 0{\cdot}875776\,d^4$.
Let R = the radius of the circumscribing circle.
r = the radius of the inscribed circle.
Then

$$\tfrac{1}{4}b^2 = R^2 - d^2;\ r = d;$$
$$\therefore (28) \text{ becomes } I = \tfrac{1}{12}A(R + 2r).$$

If $r = R$, then $A = \pi r^2$; $\therefore I = \frac{1}{4}\pi R^4$, which is the moment of inertia of a circle as before found.

For the Journal of the Franklin Institute.

A Mode of Determining Graphically the Correction for the Reduction to Centre of Station, and also for Oblique Illumination on Signals in a Geodesic Survey. By JOHN R. MAYER, C.E.

Reduction to the Centre of Station.

C being the centre of a trigonometrical station, O the angle observed between two objects A and B, y the angle between C and B, the *left* hand object, r the distance O C, D the distance A C, and G the distance B C.

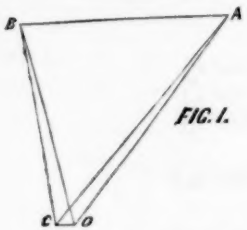


FIG. 1.

Correction expressed in seconds

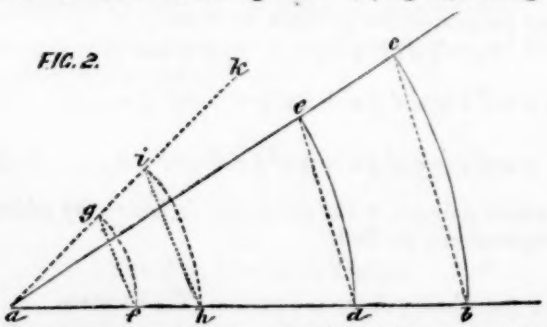
$$= \frac{r \sin (o + y)}{D} R'' - \frac{r \sin y}{G} R''.$$

In the first term call $\sin (o + y)$, a, and we have for this term $D : R'' :: \frac{D}{1000} : \frac{R''}{1000} ::$ $(r\,a)$: correction for the first term.

The quantity $r\,a$ is obtained by a fourth proportional between 90° or radius, r and a the value of this last quantity being taken from the table of natural sines.

Thus we construct a sectoral figure $a\,b\,c$, (Fig. 2,) having $a\,b$ for radius, and the transverse $b\,c = r$, on which the natural sine of a is marked on the lines $a\,b$ and $a\,c$ at d and e from the centre a, which gives $d\,e$ for the quantity $r\,a$.

FIG. 2.



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Then, on the same figure *a b c*, describe an arc *f g*, with a radius equal to $\frac{D}{1000}$, and intersect this arc at *g* with the quantity $\frac{R''}{1000}$, and draw the line *a g k*. Then, from *a* as a centre, describe an arc with *d e* as radius which intersects the lines *a b* and *a k* at *h* and *i*, the distance *h i* will represent the number of seconds for the correction of the first term.

The same operation is required for the second term,

$$\frac{\frac{r \sin y}{G}}{1000} \frac{R''}{100}.$$

The rule of signs is to make the first term *positive* when $(o + y)$ is less than 180°, and apply the negative sign with sin *y*.

The same scale of equal parts is used for the quantities *r*, $\frac{D}{1000}$, $\frac{G}{1000}$, and $\frac{R''}{1000}$. $R'' = 206264''{\cdot}8$.

EXAMPLE.—Suppose $o = 51° 46' 38''$, $y = 79° 24'$, $r = 5{\cdot}50$ feet, $D = 27659{\cdot}6$ feet, and $G = 22245{\cdot}4$ feet.

The graphical computation gives:

First term, $+ 30''{\cdot}75$; second term, $- 50''{\cdot}05$. Correction $= - 19''{\cdot}30$.

The computation with the table of logarithms gives:

First term, $+ 30''{\cdot}87$; second term, $- 50''{\cdot}12$. Correction $= - 19''{\cdot}25$.

Correction for Phase when a Tin Cone or Cylinder is used as Signal.

z being the angle observed at the station between the sun and the signal, *r* the radius of the signal, and D the distance.

$$\text{Correction} = \pm \frac{r \cos^2 \frac{1}{2} z}{D} R''.$$

Substituting $\frac{1}{2}(\cos z + 1)$ to $\cos^2 \frac{1}{2} z$ and calling β the value of $\frac{1}{2}(\cos z + 1)$ from the table of natural cosines, the quantity $r \frac{1}{2}(\cos z + 1)$ or $r \beta$, will be the fourth proportional between 90° or radius, *r* and β. Then, dividing D and R'' by 1000, we have

$$\frac{D}{1000} : \frac{R''}{1000} :: r\beta : \text{correction.}$$

The construction of the sectoral figure to solve this problem is like the above-mentioned, (Fig. 2.)

With a radius of *about six inches*, this mode of graphical computation gives results which can approximate to less than *a five-hundredth of an unit.*

MECHANICS, PHYSICS, AND CHEMISTRY.

On Improvements in Heavy Tools for General Engineering and Iron Ship-building Work. By Mr. JAMES FLETCHER, of Manchester.

From Newton's London Journal of Arts, August, 1865.

Forty-five years ago, at the commencement of the writer's career as a mechanic, tools were of a very rude and primitive description, the lathe and drill being about the only ones then in general use; slide lathes were possessed only by a few persons, being made with great labor and expense, and very inferior in point of workmanship.

The introduction of the planing machine, however, and its subsequent development, effected an entire change in the manufacture of tools and machinery of every class, giving the means of carrying out with facility many works which had been left unattempted previously as too expensive or impracticable, and opening the way for improvements and invention generally; and in a short time these machines became indispensable in every workshop. The slide lathe became then comparatively easy of manufacture, and, in conjunction with the planing machine and self-acting drill, formed a most important feature in the advancement of engineering work. Still, much remained to be effected; a large proportion of work was done by hand, especially the smaller portions of machinery, until slotting and shaping machines were brought into use, and special tools adapted for all parts where a quantity of work was required to be produced. By the gradual introduction and perfecting of the regulator screw, the wheel-cutting engine, standard gauges, large surface plates, long straight edges, and scraped surfaces combined with the improved tools, not only was the amount of manual labor considerably diminished, but the work was done more expeditiously, and a much greater degree of accuracy was attained, whereby the workmanship in all classes of machinery was remarkably improved, and at a great reduction in cost. As engineering skill was brought to bear on schemes which could not previously have been carried out, so were tools enlarged and new ones invented, to meet the exigencies of new works, until engineers and others became really dependent for the accuracy and execution of their work upon the tools that could be employed for the purpose. The steam engine, with all the inventive genius that has been concentrated upon it, would, without these tools, have still been most imperfect in construction, and would have formed a wide contrast to the engines erected at the present day, in point of excellence of workmanship, durability, and cost. Many instances could be given where tools of unusually large dimensions or the most minute description are indispensable for the execution of the work required.

The great change which has taken place in the substitution of wrought iron for wood or cast iron, especially in ship and bridge-building, is a subject worthy of special attention. In ship-building, the use of wrought iron has advanced with such rapid strides during the last twenty years, as to cause a complete revolution in the trade. The transition was so sudden and the demand so great, that much difficulty was experi-

enced in procuring a sufficient number of the necessary class of workmen, until those who had been previously employed as shipwrights in building wooden vessels were, in a short time, enabled, by the assistance of improved tools and appliances, to compete with more practised hands, and to cope easily with the heavy modern work. Improvements in the construction of iron ships were then rapidly developed. New tools were called for and produced, by means of which the work has been materially improved and facilitated; the edges of the plates are now planed, to make perfectly fitting joints, and multiple drilling machines are rapidly coming into use for drilling a large number of holes at once in the plates or keel bars.

Another important feature in connexion with improved tools, is the direct application of steam power to individual machines, especially those for the purpose of punching or shearing plates or cutting bars, &c., by the combination of a small steam engine with each machine; thus rendering the machines portable, entirely self-contained, and independent of other sources of driving power, and thereby saving, in many instances, the necessity of running a large engine and quantity of shafting to drive only one or two machines, when pressed for the work upon which they are engaged, and entirely dispensing with shafting and the usual attendant expenses. By this means, and by the use of an under-ground steam pipe with branches at convenient points, either in workshops or along the sides of docks, these machines may be moved about to any part required, and thus obviate the inconvenience and loss of time in carrying work to and from the machines. Steam pipes of great length are now being used, and are found very satisfactory for purposes of this description; and this plan makes a much more convenient and less costly arrangement than shafting, which requires constant attention.

In the earlier construction of the lathe, the slide rest was the first great step towards the principle of the slide lathe, and no doubt led to that invention, which was considered impracticable before planing machines were made of sufficient magnitude to plane a lathe-bed of even small dimensions. A few slide lathes had indeed been made, the beds of which were composed of a timber framing, covered with iron plates on the upper side to preserve the surface, similar to those which were previously used for the ordinary hand lathes, with the exception that the outer edges of the iron plates were made of suitable shape to form the Vs for the carriage to slide upon. It was not, however, until some time after the introduction of the planing machine that—the cost of workmanship being considerably lessened—slide lathes came into general use, and their utility was fully acknowledged, and attention directed to their improvement.

The application of a screw to the slide lathe, so as to render it capable of both sliding and screw-cutting, was the next important improvement; and a great amount of time, perseverance, and capital was expended by a few persons in endeavoring to perfect this portion of the lathe. A short screw was first made, as accurately as possible with the rude means then possessed, from which one was cut double the

length, by changing the turned bar end for end in the lathe after cutting one-half. Subsequently, by following out this principle, screws were capable of being made of any length required.

After this, the surfacing motion was introduced, and also the use of a shaft at the back of the lathe, in addition to the regulator screw, for driving the sliding motion by rack and pinion, instead of both the motions of sliding and screw-cutting being worked by the screw alone; for it was found that the threads of that portion of the screw nearest the fast head-stock, being most in use, were worn thinner than the other parts; and, in consequence, the lathe did not cut a long screw with the degree of accuracy which it otherwise would have done.

Thus, step by step, improvements were gradually brought forward; the fore-jaw and universal chucks and other important appliances were added, so as to render the lathe applicable to a great variety of work, even cutting spiral grooves in shafts, scrolls in a face-plate, skew wheels, and also turning articles of oval, spherical, or other forms. The duplex lathe, with one tool acting in front and the other behind the work, is also found to be a very useful arrangement for turning long shafts, cast iron rollers, cylinders, and a great variety of work, where a quantity of the same kind and dimensions has to be turned.

An improved lathe, referred to by the author, and designed for the purpose of turning long shafts, screws, or other articles, had a bed 40 feet long, cast in one piece, and planed the entire length at once. It is provided with two pairs of head-stocks, placed right and left hand, each pair having its own carriage and tool-rest, and working entirely independent of the other, the one pair being 15 inches high to the centre, and the other 12 inches high. In connexion with the larger head-stock is a regulator screw, running through the entire length of the bed, by means of which, when the other head-stocks are removed, a screw, 35½ feet long, may be cut at once. The smaller head-stocks, by means of a separate shaft at the back of the lathe, are capable of sliding an article 25 feet long, and can also, if required, be provided with a screw-cutting arrangement. Thus this lathe possesses the advantages of being used as two lathes for work of an ordinary character, but at the same time a very long shaft may be turned when required. In many workshops a long lathe is an absolute necessity, although the whole length of the bed may not be required many times in the year; and unless some similar arrangement to the one above described is adopted, a large portion of the lathe-bed, taking up valuable space, would remain idle and useless the greater portion of the time. Again, in sliding long shafts, the two carriages and tools may be in operation at once upon the same piece of work, and thus economize time. The head-stocks being placed right and left hand, the loose head-stocks are thus able to accommodate each other to the different lengths of work; thereby avoiding the necessity of moving the fast head-stock and top cone-pulley when any work above half the total length of the bed is to be turned.

For turning large marine engine crank-shafts or other articles up to 40 tons weight, or screw propellers up to 20 feet diameter, the author

referred to a slide lathe, the head-stocks of which are 4 feet 6 inches high from the face of the bed, which is 40 feet long. The main driving spindle is of cast iron, 18 inches diameter in the front bearing, and 12 inches in the back bearing, arranged as an ordinary treble-geared lathe, which can be worked single, double, or treble power. The cone-pulley, the largest speed of which is 3 feet 6 inches diameter by 6 inches wide, runs loose upon the spindle. The face-plate is 12 feet diameter, and has on the back a large internal toothed wheel. By means of two pairs of driving pulleys on the counter shaft, the lathe may be worked at thirty different speeds, to suit the diameter of articles to be turned. The fast head-stock casting is in one piece, and, without spindle or appurtenances, weighs 11¼ tons. It is secured to the bed by the tie-plates. The bed is 10 feet wide over all, and is composed of two lathe-beds, each cast in one piece 40 feet long, and held firmly in a parallel position by distance feet or foundation plates, having strips and bolts to bind the beds in their places. When it is required to move the bed endways, to accommodate any large article on the face-plate, the strips in the distance feet are slackened so as to allow the two long beds to slide through them, the motion being given at the end by means of worm-wheels and screws. The end foot or distance piece nearest the fast head-stock is fixed to the long beds, and travels with them upon the tie-plates, so as to support their ends whilst turning articles on the face-plate. Two self-acting sliding carriages are employed, upon one of which is a slide rest of ordinary construction and great strength; the other carriage has a rest made very narrow, with a wrought iron tool slide, and is for the purpose of turning out crank sweeps. The self-acting motion is driven by a strap from the spindle to a pulley at the back of the lathe, and is provided with a reversing apparatus, to enable the carriage to slide in both directions. This motion can be thrown out of gear independently in either of the carriages, which are provided with an arrangement for moving them on the bed by hand. An eye bolt is screwed in the front part of the loose head-stock, and a corresponding one upon the nearest carriage, so that the two can be coupled by a short chain or shackle, and the loose head-stock can thus be drawn upon the surface of the bed, to any required position, by the hand motion of the carriage. The total weight of this lathe, which is now in course of construction for the Lancefield Forge, in Glasgow, will be upwards of 70 tons.

The planing machine is one of the most important tools in use, and has done more towards the advancement and success of engineering work than any other invention, with the exception of the lathe, and has passed through a great number of changes since its first introduction down to the present time.

In the first planing machines the table was moved by a chain winding on a drum, as in the old hand machines; but this mode was found to be very objectionable, the cut was unsteady, and when the tool was suddenly relieved at the end of its cut, the table had a tendency to spring forwards; it was also driven at the same speed both forwards and backwards, and thus a great loss of time was occasioned. This

was much improved upon by the use of a rack and pinion, arranged to give a quick return motion, and also afterwards by the screw arrangement.

In some of the earliest planing machines the Vs were made inverted, evidently with the idea of preventing any cuttings that fell upon the wearing surfaces from remaining upon them. They proved, however, to possess no advantage even in this particular, as the finer portions of the cuttings still adhered; and in addition it was found that, from the motion of the table, the oil, by its own gravity, would not remain upon the surfaces, and thus caused them to cut and wear away quickly.

The writer has in use a planing machine, with a bed 54 feet long, the Vs of which have 2 inches of surface on each side, and are planed to an angle of 85 degrees. This machine has been working upwards of twenty years, and for the last six years both night and day. It has been employed during the whole of that time upon very heavy work, ranging from 5 to 20 tons. The Vs are still in good condition, apparently very little worn, and the work the machine does is at the present time perfectly true. The bed is in three parts jointed and bolted together, and the table in two parts; since, at the time it was made, there was no machine capable of planing a very long piece, and this was considered to be one of the largest then in existence.

The planing machines were further improved by the use of two tool-boxes on the cross-slide, and by the application of slide rests or tool-boxes fixed upon the uprights, self-acting vertically, for planing articles at right angles to the tools on the cross-slide. The reversing tool-box is a very ingenious and useful contrivance for planing flat surfaces; but that plan is not so well adapted for general purposes. Planing machines have, like other tools, been specially adapted to a great variety of work, and the writer has made them with different numbers of tools up to as many as sixteen, all of which were in operation at once.

The great changes which have lately taken place in the manufacture of wrought iron and steel ordnance, and the revolution they have caused in the construction of vessels of war, have called into requisition a great many alterations and adaptations of the present machines, as well as many entirely new ones. The planing machine especially has been called upon to do work of a very curious and intricate character, namely, that of planing the edges of armor plates to different curves, shapes, or angles. In most cases this has been accomplished by a pattern bar of iron or steel, placed on edge in a small chuck fixed upon the surface of the table, adjustable by set screws, and shaped to the form to which it is required to plane the edge of the plate; as the table travels, this bar, which runs between two circular rollers attached to the under side of the cross-slide, moves the tool sideways, according to the amount of curve in the shaper or guide bar, the tool-box being disconnected for this purpose from the screw in the cross-slide.

A duplex planing machine, made by the writer, is arranged with double beds and double tables, each table having a separate set of gear-

ing, with starting, stopping, and feed motions. There are two tool-boxes on the cross-slide, each of which is independently self-acting, so as to work with its own table. Thus the two tables may be used separately as two smaller machines working independently of each other, and capable of planing different lengths of work at the same time; or when planing a large article, the two tables, gearing and motions, may be coupled, so as to form one large machine, an arrangement rendering the machine capable of doing a variety of work. Also one table may be fixed stationary as a bed-plate to bolt awkwardly-shaped or long pieces of work upon, whilst they are planed by a slide rest fixed upon the other table. When used as one machine, both sets of straps and gearing are in operation, and are reversed by the stops of one table only, so as to insure the straps moving at the same time.

This machine is capable of planing articles 10 feet wide and 10 feet high. The racks on the under side of the tables are 3 inches pitch, with stepped teeth; the wheel working into the rack is 3 feet 9 inches diameter at the pitch line, and is driven by a smaller pinion. By this arrangement a steadier motion is obtained; and also the pulleys and driving gear can be placed entirely behind the face of the uprights, so as to leave the front of the machine perfectly clear, that the straps may not be in the way when taking the work off and on. The pulleys being below the ground line, may be driven by a horizontal underground shaft at the back of the machine, and no straps will then be visible. The writer has made machines of this description with beds 40 feet long, to plane work up to 14 feet in width.

This machine is particularly well adapted for planing armor plates. Two plates can be planed at once on each table, one being placed upright and the other horizontal, so as to be operated upon by the tools on the cross-slide and the upright at the same time; or whilst two plates are being planed on one table, the workman may be fixing two more on the other, and thus keep the machine constantly employed. One workman is sufficient to attend to both sides of the machine, thereby saving labor. By having a stationary table fixed at one side of the bed, upon which the four ends of four other armor plates are bolted, and adding an angle bracket and slide rest upon one of the moving tables, the four ends are planed at the same time.

The slotting machine, of which the engineers in Glasgow can justly boast the heaviest examples, was originally introduced for cutting small wheels, levers, &c., mostly for self-acting mule and loom work, and was afterwards adapted to a great variety of work by the application of a circular table, which was an improvement of the greatest importance, especially in large machines for slotting or shaping large cranks or other similar work; this is now done to such perfection as to require merely drawfiling and polishing to give the work a perfect finish. Many kinds of quick return motions have been employed for the purpose of saving time in the return stroke of the tool, and to give it a regular and steady movement in the cutting direction. Of these, the principal are the eccentric wheels, the eccentric motion, and, lastly, the lever motion, which makes an excellent and steady movement, and is now very much applied to shaping machines.

One of the large slotting machines made by the writer has a stroke of 3 feet, and the framing is capable of taking in an article 12 feet diameter; it has compound slides and a self-acting circular table 6 feet diameter. The ram moves in a vertical slide, which can be raised or lowered to suit the depth of work on the table, so as to form a support to the ram when taking a heavy cut. The motion applied to the tool slide is the lever and connecting rod, arranged so as to gain power and give an almost uniform motion in the cutting direction, and an accelerated speed in the return stroke.

In making a double lever-punching, shearing, and angle iron cutting machine, the strong hollow cast iron frame is planed at each end for the reception of the punching and shearing slides. The machine is put in motion by a steam engine, fixed upon the outside of the framing, and connected to a crank-pin in the fly-wheel, driving by a pinion on the first motion shaft into the large wheel, which has cams cast on each side in opposite positions, so as to work alternately the pressing levers, which operate the punching and shearing slides. These levers work on fixed pins for their fulcrums. The punching slide is provided with a block, which can be drawn out from under the end of the lever to throw the punch-slide out of gear. At the shearing end an adjustable stop is added immediately in front of the shears, for holding down the plate whilst shearing, and thus causing it to be cut square on the edge. This takes the strain of holding down the plate from the workman, and prevents short pieces of metal from getting down between the cutters and breaking the machine.

Upon the end of the centre shaft is forged an eccentric, working into a block in a ram, the lower end of which is provided with suitably shaped cutters for shearing bars of angle iron. This slide is placed at an angle of 45 degrees, and has also a disengaging motion, so as to be thrown out of gear whilst a long bar of angle iron is being put between the cutters, and set to the proper place or marks for being cut off correctly.

This machine possesses all the advantages of the old lever machine and the eccentric machine combined, the former of which has long been acknowledged to be the most simple and useful. The cams which operate the pressing levers are constructed of such a shape that the operation of punching or shearing is completed, and the slide returned to the top, in half a revolution of the machine, the whole slide remaining stationary during the other half revolution, whilst the workman is adjusting the plate for the next stroke. This enables the machine to be worked one-third quicker than eccentric machines, and still leaves the workman as much time to move the plate; since in eccentric machines the punch or shears is always being either raised or lowered, instead of being stationary during part of each revolution.

For the purpose of obtaining greater accuracy in dividing out the holes in bridge, boiler, or ship plates, a dividing table has been used, and machines have been arranged to punch several holes at once. This was certainly a great improvement upon the old method, since, in addition to the accuracy attained, very much more work was accomplished

in the same amount of time. Still the work was not of a satisfactory description. In punching the holes the iron is disturbed or fractured for some little distance around the hole, thus weakening the plate; and in consequence of the taper which there must necessarily be in all punched holes, the rivets do not thoroughly fill up the space, especially when more than two plates are joined together.

The faults of punched work above mentioned were so apparent when wrought iron bridge-building became general, that they led to the introduction, by Messrs. Cochrane, of the multiple drilling machine, for drilling a large number of holes at once in bridge plates.

It has been found desirable to make this principle of drilling machine more universal in its application, and the following is a machine designed for this purpose: A strong base plate extends the entire length of the machine, about 18 feet, with three circular openings along the centre line, large enough to admit hydraulic cylinders, by which the table carrying the plate to be drilled is raised and pressed against the drills with the necessary force. The end frames are bolted to the base plate, and upon them are fixed guides adjusted to each corner of the table; they also support the girder which carries the drill frames. The ends of the girder are fitted in planed grooves, and it is made in halves, which can be set wider apart without altering the gearing, by inserting cast iron packings of the requisite thickness and longer bolts at the joint. The two halves of the girder can also be turned with the drill frames inwards if required, and adjusted to a distance of four inches apart for the two rows of holes and upwards.

Each drill is held in a separate frame. The frames are all bolted on the girder at a proper distance apart, and are moveable longitudinally to any position along the girder. Each drill spindle is fitted with an adjustable tail pin and lock nut, which receives the upward pressure of the spindle; and a conical bearing is provided at the lower end of each drill frame, which prevents the drill spindles from wearing out of truth. The drills are all turned parallel for a short distance at the upper end, and fit in parallel sockets, which admit of short drills being adjusted to the same length as longer ones, by putting some small burrs or punchings from the punching machine, of the required thickness, into the drill sockets above the drills; and the drills are fastened in the sockets by a set screw.

Each drill spindle is driven at the top by a pair of mitre wheels, which may be described as each consisting of a short section of a $3\frac{1}{4}$ inch diameter twelve-threaded screw, of which the threads are about 12 inches pitch; that is to say, each thread or tooth, if continued, would make one complete turn round its shaft in 12 inches length. A long steel shaft, $2\frac{1}{4}$ inches diameter, with a groove throughout its length, passes through each drill frame, and its vertical spur mitre wheel, giving motion to each drill spindle. This shaft is driven by a pair of strong bevil wheels in the proportion of $1\frac{1}{2}$ to 1, which take their motion direct from the pulley shaft, and give about 60 revolutions per minute for the drills.

The application of the spur mitre wheels in this machine for driving the drill spindles, enables the spindles to be arranged in such a manner that they are capable of being moved to suit different pitches of holes. In consequence, however, of the wheels being 3¾ inches diameter, holes could not be drilled at a less pitch than that dimension with a single driving shaft; but another application of the same mode of driving allows of the drill spindles being got to within 2½ inches from centre to centre, with the same diameter of driving wheels. This is effected by using two long steel driving shafts, instead of a single one, each shaft driving every alternate drill spindle.

The hydraulic cylinders used to raise the table with the work on it up to the drills are similar to those of hydraulic presses. A pair of strong 1¼ inch diameter pumps, worked by eccentrics on a shaft, force water into an accumulator, which consists of an upright cylinder fitted with a piston properly weighted; and there is a self-acting apparatus which throws the pumps out of gear when the accumulator is full. The hydraulic cylinders are connected with the accumulator by a two-way cock, and on turning the water on the table immediately rises. When the pressure is to be removed, turning the cock back stops the pressure from the accumulator, and at the same time allows the water to escape from the cylinders, causing the table to fall immediately. The working pressure of water is about 3 cwt. per square inch, which produces a pressure of about 6 cwt. per drill. A plate is drilled in twelve to fifteen minutes. A strong parallel motion gear is fixed under the drill table to prevent it from lifting at one end when only the drills at the other end are being used, or when only one row is in use.

These drilling machines are now being used by Messrs. Kennard for drilling the plates and bars required in the main girders of the new bridge to be placed over the Thames at Blackfriars. The truth of the drilled holes is so complete that when a number of plates with holes drilled for 1 inch pins are put together indiscriminately, and four turned pins passed through the corner holes, the holes fit so accurately throughout the entire lot of plates, that a pin 1 inch diameter can be driven through the lot at any hole with a light hand hammer. In consequence of this superiority of the work, a great diminution in the cost of labor takes place in putting the parts together, saving the drifting of the holes and the strain put upon the plate which necessarily takes place when riveting punched holes. In addition to this, the fibre of the iron retains all its strength and tenacity, and there can be no doubt that the extra work of manufacture is fully compensated for by the greater strength of construction, and the decrease of cost in putting the plates together.

Several other useful machines are constructed for bridge and ship-building purposes, amongst which may be named—a machine for shearing plates up to 1 inch thick, with revolving circular shears; machines for planing plates with a traveling tool, and also with a revolving circular disk containing a number of tools; and machines for bending garboard strakes, angle iron, and deck beams for ships.

The writer next decribes a nut making machine, designed to manu-

facture nuts from a heated bar of iron, at a single operation, by cutting off from the bar a piece to form the blank, which is swaged into shape, and the hole punched through it while still hot. The blank is powerfully compressed between the pair of swages while in the die-box, before the hole is punched, in order to make the nut solid and shape it with smoothness and precision; and the hole is then punched while the nut is still confined in the die-box, and under the heavy pressure of the swages, so that it is prevented from bursting or straining during the operation of punching.

The dies, swages, and punch are so fixed to the machine that they can easily be removed and replaced by others of different sizes. By this means the same machine may be used for making nuts of various sizes and shapes. Two of these machines have now been at work at the writer's works in Manchester for upwards of five years. With the aid of a good furnace, from 15 to 20 cwt. of $\frac{3}{8}$ or 1 inch nuts can be produced in a working day of 10 hours, the machine running at 60 revolutions per minute. All the nuts possess the same degree of accuracy in shape, the sides being parallel to each other, and the holes being punched perfectly central whilst the nut is under pressure in the die-box. The iron is fed into the machine at a welding heat, and the pressure put upon it by the swages in the die-box has the effect of closing up the fibres of the iron, making the nuts very much stronger than those forged in the ordinary way by hand. The holes punched are perfectly clear and regular, and have no scale inside them to injure or chafe the threads of the taps when being screwed.

The author also describes a bolt-heading machine, similar in some of its principal parts to the nut-making machine. The bar of iron for forming the bolt, heated to a welding state for a short distance only at the end, and of the same diameter as the screwed portion of the bolt, is inserted between a pair of open dies, divided longitudinally down the centre. The bolt is pushed up to the heading swage, the length of which is adjustable so as to measure off the iron to the correct length for making bolts of different thicknesses of head. As soon as the bar is inserted between the dies, a shearing slide, carrying one of the dies and the cutter, is pressed forwards, and the length for forming the bolt is cut off. The second bolt is then held firmly between the dies until the formation of the head is completed. This operation is affected by the advance of a centre ram, carrying the heading swage, which compresses the heated metal so as to fill a die-box and form the bolt-head. The heading swage then remains stationary whilst the die-box is drawn back clear of the bolt-head; after which the swage also retires to its original position. The shearing slide is then withdrawn by leaving the bolt in the stationary half of the dies; and a knocker strikes the finished bolt, and discharges it from the dies.

This machine makes about 30 strokes per minute, and is capable of producing a bolt at each stroke, provided it be supplied with the iron at a proper heat. The bar of iron is heated only at that portion which is to form the head, the remainder or bolt end being cut off cold. The object of this is to prevent the bolts from being scaled their whole

length through the action of the fire. The ram carrying the heading swage is acted upon by a cam through the intervention of a lever, through which the whole pressure is transmitted; and the bottom end of this lever is centred upon an oak beam fixed inside the framing of the machine, which, being slightly elastic, prevents the machine from being broken in the event of more iron being inserted into it than is required to make the bolt-head. In consequence of this provision a bolt has been made without breaking the machine with a head as much as $1\frac{3}{16}$ inch thick, when the dies were set to make it only $\frac{7}{8}$ inch thick.

There are a great variety of special tools, for railway and machine making purposes, which the writer has been obliged to pass over, and which would form ample material for another paper.

In conclusion, it may be remarked that the opinion is now universal that, without extraordinary strength, rigidity, and power in tools their work cannot be accomplished either quickly or well. Accuracy in the manufacture of tools and their universal application have had a great effect in the perfection of the work executed and in the facility and economy of its performance. By the assistance of gauges for different parts of machinery, the advantages of engineering tools have been more fully realized; and no engineering work, of whatever magnitude, need now remain unaccomplished for want of tools.

Notwithstanding the length of time during which the improvement of tools has been in progress, and the great advance that has been made, it may be said that at the present time there is a wider field for improvement than ever, and a constant and increasing demand for tools of novel construction for special purposes.

Number of Useful Plants.

From the London Reader, May, 1865.

"Cosmos" states that, according to a German author, the number of useful plants has risen to about 12,000; but it must be remembered that these researches have been completed only in certain parts of the earth. There are no less than 2500 known economic plants, among which are reckoned 1100 edible fruits, berries, and seeds, 50 cereals, 40 uncultivated edible graminaceous seeds, 23 of other families, 260 comestible rhizomes, roots, and tubers, 37 onions, 420 vegetables and salads, 40 palms, 32 varieties of arrowroot, 31 sugars, 40 saleps. Vinous drinks are obtained from 200 plants, aromatics from 266. There are 50 substitutes for coffee, 129 for tea. Tannin is present in 140 plants, caoutchouc in 96, gutta percha in 7, resin and balsamic gums in 389, wax in 10, grease and essential oils in 330. 88 plants contain potash, soda, and iodine, 650 contain dyes, 47 soap, 250 fibres which serve for weaving, 44 for paper making, 48 give materials for roofing, 100 are employed for hurdles and copses. In building 740 are used, and there are 615 known poisonous plants. According to Endlicher, out of the 278 known natural families, 18 only seem up to the present time to be perfectly useless.

Professor Graham's Law of Gas Diffusion.

From the London Reader, May, 1865.

Mr. G. F. Ansell, of the Royal Mint, has proposed a novel application of Professor Graham's law of gas diffusion for the purpose of ascertaining and giving warning of the presence of accumulations of fire damp in coal mines. The apparatus described by Mr. Ansell is a glass U-tube, having one aperture closed with a plate of graphite or equivalent porous diaphragm, and a few inches of mercury in the bend. If such an arrangement, filled in the first instance with air, be placed under the influence of an atmosphere containing five per cent., or even less, of light carburetted hydrogen or marsh gas, the presence of such admixture will be instantly detected by the passage of the gas through the interstices of the graphite, and the consequent expansion in volume of the gaseous contents of the tube; the column of mercury then rises in the opposite limb of the apparatus, and is made to record itself either by completing the circuit of a voltaic alarum, by deflecting a galvanometer needle, or, lastly, by an adaptation of the simpler mechanism of a wheel barometer. We understand that the invention has been patented by Mr. Ansell, and, inasmuch as it gives great promise of successful employment, the apparatus must be deemed well worthy of immediate trial.

Cornish Engines.

From Herapath's London Railway Journal, No. 1376.

The number of pumping engines reported this month is 31. They had consumed 1905 tons of coal, and lifted 12,800,000 tons of water 10 fathoms high. The average duty of the whole is therefore 48,700,000 pounds, lifted one foot high, by the consumption of 112 pounds of coal.—*Lean's Engine Reporter for August.*

Report of the Balloon Committee.

From the London Mechanics' Magazine, September, 1865.

This report was read by Mr. Glaisher. It stated that the committee had been reappointed last year in order, first, to examine the electrical condition of the air at heights; second, to verify the law of the decrease of temperature, as found from summer-day observations already made, with day observations at other seasons of the year, but principally in the winter and the adjacent months; third, magnetical experiments, observations with the spectroscope, the currents of the atmosphere, solar radiation at different heights, and hygrometrical observations, though secondary, were held as very important subjects of investigation; fourth, to arrange for observations at night, and to make such observations if possible. With respect to the first subject no further progress had been made, the instrument prepared for the purpose not having been rendered available for use. Under the second and third heads some progress had been made, though not to the ex-

tent anticipated. As to the fourth object, no night observations had actually been made. To take such observations it was imperatively necessary to have some means of illumination, so that the instruments could be read. Various suggestions had been made on this point, but the best plan seemed to be to employ a Davy lamp. Two such lamps had been made for Mr. Glaisher of copper, so that the proximity of magnets did not affect them. Experiments had shown that these lamps might be used with perfect safety, and that they kept well alight, besides affording a source of grateful warmth not before possessed. All necessary arrangements were now made for night observations, though there were no results yet for presentation, and a series of such observations would be very useful. The same instruments, with the addition of a fine spectroscope and a delicately mounted magnet, had been employed, as during the previous year. The instruments were attached to the outside of the car, and were easily read in that position. Up to the last meeting of the Association, twenty-two ascents had been made, of which seventeen had taken place in June, July, August, and September, and five only in the other months of the year, viz: one in January, one in March, two in April, and one in October. Of the summer ascents, one had been made in the morning, and the rest in the afternoon or evening. The committee considering that day and high experiments in summer had better be brought together before more were made, Mr. Glaisher devoted all his efforts to secure as many ascents as possible between October and April, but he had succeeded in three instances only, on December 1 and 30, 1864, and on February 27 last. The three ascents were made at Woolwich, and the paths of the balloon were shown in diagrams. The small number of ascents was due to winter being an unfavorable season for balloon experiments. But as with regard to the progressive diminution of temperature with elevation, the diffusion of vapor in the atmosphere, the density of clouds, their extent, and currents in the atmosphere, and all connected with the higher regions of the atmosphere in winter, we are in almost entire ignorance. It is the most important season for experiments. Proceeding to speak briefly of the three ascents, the report stated that the balloon left the earth on December 1 at 2·37 P. M., with a temperature of 48 degrees, which remained almost unaltered till the height of 800 feet was passed. Having slightly increased up to that point, it then gradually declined to 31½ degrees at about a mile high. On December 30 the balloon left at 2·13 P. M., with a temperature of 42½ degrees. In the first 500 feet it inclined 2 degrees, at 1000 feet it was 37 degrees, at 2000 feet it was 33½ degrees, at 2500 feet cloud was encountered, and the temperature was 31 degrees; at 3300, at the upper surface of the cloud, it was 27 degrees, on getting above the cloud the temperature rose, and at 400 feet above it had increased to 31½ degrees. On February 27 the earth was left at 1·58 P. M., the temperature was 52 degrees, and declined gradually to 35 degrees, when a cloud 1000 feet in thickness was reached. In passing through this there was no change of temperature, but above it the temperature increased with elevation. Comparison established that these

results differed greatly from those obtained in summer, and showed that the laws of temperature varied at different seasons. The courses in the three ascents were very nearly the same after reaching a certain point. The winds prevailing in the higher regions in January and February were W. and S.W. This was unfortunate in regard to the ascents, as it necessarily shortened their duration. Since that time Mr. Glaisher has been making preparations for night ascents. The ascents made, however, were important in proving the constancy of the S.W. current during the winter months, which was also confirmed by observations at the Royal Academy. In the descent on December 30, Mr. Glaisher was unable to make any magnetic observations, as the balloon was in a constant state of revolution, but on other occasions he had succeeded in obtaining results which corresponded with those found at other periods of the year. At every opportunity during these ascents, Mr. Glaisher had directed the spectroscope to the sun, and always saw a very fine spectrum with many lines, more numerous than on earth and better defined. The spectrum usually extended from A to far beyond H. The spectrum was perfect, with a much narrower opening of the slit than on the ground, and lines could therefore be clearly resolved which could not be seen from the earth. A blackened bulb thermometer, placed near another carefully screened, for determining the temperature of the air, generally read the same as the latter. No tinge of ozone was shown on the test papers in any of the journeys. The report contained a mass of figures relating to the observations, which were detailed with every minuteness.

Mr. Glaisher's disappointment at finding his time for observation always cut short by the inevitable tendency of the balloon towards the sea, was compensated for when he considered the high importance of the continuance of southwest winds in winter. Constant observation last winter, from October to March, had found the wind always in the same direction, whenever it was possible to determine the motion of the upper air, no matter from what quarter the earth wind came. The high temperature we experienced in winter seemed due greatly to this current, which met with no obstruction in its course towards us, but blew directly hither and to Norway over the Atlantic. These winds only reached France when they had passed over the whole of Spain and the Pyrenees, and they had then become so much cooled that France derived comparatively little benefit from them. This apparently caused the more severe winters in that country. It was probable that our milder winters were due to these winds. After touching on the subject of the ultimate destination of the heat rays which constantly issue from the sun, Mr. Glaisher said that a few months previously he had thought that would be his last report on balloon ascents. He had devoted his entire leisure for three years to these experiments, and every day he was so occupied was a day taken from the month's holiday allowed him as an *attache* of the Royal Observatory. As, very properly, no personal expenses were allowed by the Association, he had to pay them himself, and he had also had to defray the cost of the necessarily heavy calculations. He felt, therefore, that he had per-

formed his share of these experiments, and that they might cease for the present, and fresh ones be made at a future day by others. But on seeing, in preparing this report, how deficient they still were in winter ascents and morning ascents, but, above all, in night operations, he had determined, in consultation with the committee, to make some night ascents at once, if possible, and therefore he would probably have to address them again at their next meeting.

The Explosion at the London Gas Works at Nine Elms.

From the London Journal of Gas Lighting, No. 341.

The evidence adduced at the coroner's inquest may be thus briefly recapitulated. The works of the London Gas Company at Nine Elms comprised two telescopic gasholders, about 4000 feet apart, each 150 feet in diameter, with two lifts of 30 feet, and, when filled, each one contained one million cubic feet of gas. The accident occurred about quarter past two o'clock in the afternoon, when the southern gasholder was quite full, and the northern one was about 38 feet high. Between the two gasholders, but within 20 feet of the northern one, was a building 79 feet long by 39 feet wide and 23 feet high, which contained the station meter in the centre, the governors being at the eastern end, with a second floor for store rooms, and workshops over them. The foreman's office, photometer room, &c., were at the west end of the building, with a second floor over them. The central part, occupied by the station meter, was open to the roof, on which was a glazed ventilator, extending the whole length of the meter-house. There was space enough in the building for a second meter of the largest dimensions, and in the south wall there was left an opening sufficient for the admission of the drum of the second meter, whenever it might be required. It was intended to close that opening with doors, but they had not been fixed, and the space was left open at the time of the accident. Two governors, one for a 36-inch main and the other for a 24-inch main, had been fixed on a stage raised about 2 feet high above the floor of the meter-house, and a third governor was in the course of erection. The gasholder of the larger governor was floated by an air vessel, and that of the other governor was counterbalanced by a weight suspended from the opposite extremity of a beam, each one being kept in position by friction rollers acting in three guide columns, and by three sets of friction rollers fixed round the bottom. At 11 A.M., the outlet and inlet valves being still open, the by-pass valve of the 24-inch governor was opened, and the gas was sent to the company's gasholders at Vauxhall. At about a quarter past two o'clock an alarm was raised that gas was escaping from that governor, the gasholder of which had been tilted, and several men who had been at work in the building were seen endeavoring to force it back into the governor tank. At that time the gas was rushing through the water with great violence. Two heroic servants of the company, Mr. Marven, the deputy manager, and Michael Doolan, the deputy valve man, saw the danger, and, at the imminent risk of their lives, rushed into the house

in the hope of preventing an explosion. Marven first extinguished the test light which was burning in the meter-house, and then assisted Doolan in closing the valves of the governor. They succeeded in closing the outlet valve, and had descended into the vault below the stage and had half closed the inlet valve when the explosion took place, which destroyed the entire building and buried about thirty men beneath the ruins, seven of whom were killed. The side of the gasholder next to the north wall of the meter-house was forced in with great violence, and the crown was rent open, the sheet iron plates being turned over outwards so as to make an irregularly shaped aperture of about 1200 feet area. Through that aperture the gas forced its way, and, becoming ignited, blazed fearfully for a few seconds till it had all escaped, and the gasholder descended rapidly into the tank. The eastern wall of the meter-house was forced against and crushed in a portion of the front wall of some workshops about 25 feet distant; but the southern and western walls were blown into the yard without doing much damage. The effect of the explosion on the second gasholder is most remarkable. Its nearest point to the meter-house was 320 feet, but the concussion cracked the sheet iron of the outer ring of the crown, between the rivets by which the plates were fastened to the angle iron curb, for a length of 6 or 8 feet on the side next the meter-house, and through that rent the gas escaped, and, becoming ignited, burned with great fury until all the gas was consumed. The gasholder was not further damaged, and in a few days it was repaired and again at work. One of the guide columns against which the flame impinged curved slightly during the burning of the gas, but straightened again on cooling, though a slight crack was produced which has been temporarily repaired by hooping it; but with this exception the guide columns of both gasholders are uninjured.

Of the persons buried under the ruins of the meter-house, seven were dead when extricated, three others died after having been taken to the hospital, and fifteen or twenty other men were more or less burned by the explosion. The escape of Marven and Doolan with trifling injuries is almost miraculous; but no damage appears to have been done to the pipes or valves in the chamber underground in which they were, and even the wooden stage immediately above them was only slightly injured. Neither is the station meter much damaged, such injury as it has received having been occasioned principally by the *debris* falling on the sheet iron cover, the case and the drum remaining untouched. The guides of the 24-inch governor were broken short off at the tank, but the gasholder itself was in its place, and it has been only crippled by the falling material. Thus it appears that, in the very midst of the flame, the gas in the governor, which was the cause of the accident, did not explode.

There are three ways by which gas may escape from governors as at present constructed. In the first place, by the detachment of the internal cone from the top of the gasholder, owing to the breaking of the link by which it is suspended, whereby the counterbalance weight would raise the gasholder out of the water. In the second place, the

gas may escape from want of water in the tank; or, thirdly, by the accidental tilting or upsetting of the bell of the governor. The evidence at the inquest shows that the latter was the cause of the escape of gas at Nine Elms. The valve man, Bartlett, stated that the "seal" was 8 inches, and as the gasholder gave a pressure of only 6 inches, there were 2 inches to spare. The cone was found after the accident to be securely suspended from the governor gasholder; therefore the accidental tilting of the bell by the plasterers at work on a scaffold in plastering the ceiling over the governor seems to be the only conclusion we can arrive at as to the cause of the escape of gas.

It is almost impossible to estimate the quantity of mixed gas and air that exploded, for the large central opening would permit all the gas below that level to pass outwards. The total capacity of the meter-house building Dr. Letheby calculates to have been 61,000 cubic feet, and the quantity of gas that might have escaped by the tilting of the smaller governor would be amply sufficient to have filled the whole area with an explosive mixture of gas and air during the few minutes that Doolan was absent to take the stock of gas. The ignition appears to have taken place at some lights in the meter testing shop, 58 feet distant from the governor. The current of mixed gas and air must have crossed a roadway between the meter-house and the workshops, and have passed through windows before its ignition; for, with the exception of a smith's fire—which was about the same distance as the lights in the meter testing shop, but opposite to which there was not any opening in the meter-house wall—there was no other light at which the ignition could have occurred.

The verdict of "Accidental death" was the only one which the jury could have rationally given after the evidence brought before them. They evidently came to the inquiry prejudiced by the erroneous and exaggerated accounts in the papers; but as the witnesses were examined they began to see the fallacy of those representations, and felt so satisfied by the evidence of Dr. Letheby that the gasholder did not and could not explode, that they did not require any confirmation of his statements, though Professor Pole, Mr. Siemens, and Mr. Barlow were present, and were prepared to do so.

The recommendation of the jury, that precautions should be taken to protect governors from being tampered with, has directed the attention of gas engineers to the methods most likely to effect that object. Mr. Watson, the Engineer of the London Gas Company, purposes to adopt the very effectual plan of enclosing the governors, and of carrying shafts from each through the roof into the open air. Mr. Evans, the Engineer of the Chartered Company, proposes to enclose the gasholders of governors in jackets with stuffing boxes at the top, through which the suspension rod can pass—a plan which has been already adopted by Mr. Garnett, of the Ryde Gas Works. Mr. Pritchard, of the Western Company, suggests a sheet iron jacket with a small hole in the centre of the crown, just large enough for the free working of a small wire rope by which the gasholder may be suspended. The last is the simplest, and perhaps the most practicable plan. It

does not in any degree affect the action of the instrument, and it has the additional advantage that the air confined in the jacket would form a cushion that would prevent the sudden rising of the cone by an increase of pressure, which has sometimes been the cause of the snapping of the link connecting the cone with the gasholder. The adoption of any one of these contrivances would, there could be no doubt, completely prevent the recurrence of such an accident as that at Nine Elms; but, above all things, we strongly recommend gas managers to see for themselves that the governors are perfectly charged with water, for which purpose a small stream might be constantly kept running through, as is done with station meters where great accuracy of registration is desired.

The district lighted by the London Gas Company was for one night deprived of gas illumination by the damage done to their two large gasholders; but the Chartered, the Imperial, the Phœnix, and the Equitable Gas Companies promptly offered their assistance, and the lighting was resumed on the following night.

The advocates of the system of laying gas pipes in subways ought to reflect upon what may be the consequence of constructing mines under crowded thoroughfares that are liable at any moment to be filled with mixtures of gas and atmospheric air equal in their explosive properties to the contents of the meter-house at Nine Elms, which has been the cause of such fearful destruction of life and property. The subway of the Holborn Viaduct, designed by the city architect, is of proportions and construction that would involve the destruction of the whole street, were any such accident to occur; and those in course of construction by the Metropolitan Board in the Thames Embankment, and in the new street, from Blackfriars to the Mansion House, though not so colossal in their proportions as that of the proposed Holborn Viaduct, partake of all its sources of danger, and the objections of gas companies to lay their mains in them will be greatly strengthened by the experience which this catastrophe has afforded. The Metropolitan Board would do well to rescind their resolution by which these structures are being formed in anticipation of the current of public feeling becoming sufficiently strong to drive the gas companies into them at some future time, as it is evident, from the panic which this explosion has created, that the public feeling is now setting in the opposite direction.

On Chemistry Applied to the Arts. By Dr. F. Crace Calvert, F.R.S., F.C.S.

From the London Chemical News, No. 252.

(Concluded from page 34.)

Lecture VI.

Flesh, its chief constituents, boiling and roasting. *Animal black*, its manufacture and applications. Various methods of preserving animal matters. Employment of animal refuse in the manufacture of *prussiate of potash*. A few words on the decay of organic matters, and their fermentation and putrefaction.

I shall now examine with you some of the various causes which contribute to the destruction of animal matters, when it arises from slow

decay or putrefaction. The first of these to which I shall have the pleasure of calling your attention is that observed by Dr. Stenhouse, who, in 1854, made the curious discovery that, if the body of an animal was buried in a carbonaceous mass, such as charcoal, after a few months the whole of the animal, excepting the skeleton, would entirely disappear; and what was still more remarkable was that, though the experiments were conducted within his laboratory, no unpleasant effluvia were apparent to those who were constantly there. This eminent chemist attributed the rapid and complete destruction of animal tissue in these experiments to the oxidation of the animal matters by the oxygen of the atmosphere; but to enable you fully to understand how this occurs, I must call your attention to the following facts: Lowitz, many years since, observed that charcoal possesses the property of absorbing and condensing in its pores large quantities of various gases, and Theodore de Saussure made an extensive series of experiments, from which I extract the following data:

One cubic inch of boxwood charcoal absorbed of—

Ammonia,	90	cubic inches.
Hydrochloric acid,	85	"
Sulphurous acid,	65	"
Sulphuretted hydrogen,	55	"
Carbonic acid,	35	"
Oxygen,	10	"
Nitrogen,	7	"

Consequently, the absorption or condensation of a gas in charcoal appears to be in ratio to the solubility of the gas in water, and although the condensation by a solid and by a liquid may at first appear necessarily due to different causes, and, therefore, to bear no relation to each other, yet, in my opinion, these two actions are identical. Seeing that the gas is condensed by the molecular attraction of the solid, I do not see why the same attraction should not be exercised by the molecules of the liquid. The different degrees of solubility of various gases are no doubt owing to their respective physical properties, such as specific gravity, repulsive or expansive forces of their molecules, &c. I may here mention that I am now engaged in a series of experiments, in the hope of throwing some light on this interesting question.

Gay-Lussac, in his researches on the condensation of gases by charcoal, found that one gas may expel and take the place of another gas already condensed in the charcoal; and Dr. Stenhouse, following up this observation, states that the gases, vapors, and sporules generated by the putrefaction of animal substances are absorbed by charcoal and brought into immediate contact with the oxygen of the atmosphere also contained in the pores of the charcoal, while oxidizing or destroying the products of putrefaction converts them into water, carbonic acid, nitric acid, &c. These important scientific observations of Dr. Stenhouse have already received practical application. Thus, Mr. Haywood has established charcoal filters at the mouths of public drains, thereby arresting the escape and diffusion in the atmosphere of the noxious effluvia given off by the putrefying matters in the sewers. Further, charcoal respirators have become extensively used since Dr.

Stenhouse called public attention to the valuable properties of this substance; and, lastly, atmospheric filters, containing charcoal, have been successfully applied in the Houses of Parliament to purify the entering air from any noxious gases it may contain before passing into the building. The natural decay or destruction of organic matters is due to two perfectly distinct causes—one of them chemical and the other physiological. The former has been investigated by many of the most eminent chemists of the day, and no doubt can remain that the action of the oxygen of the atmosphere converts the carbon of organic substances into carbonic acid, the hydrogen into water, the sulphur into sulphuric acid, the nitrogen into nitric acid, the phosphorus into phosphoric acid, &c. Much light has recently been thrown upon these phenomena of M. Kuhlmann, who clearly shows that the oxides of iron play a most important part therein; thus that the sesquioxide of iron yields its oxygen to the elements of the organic matters; that the protoxide of iron thereby formed absorbs oxygen from the air, which reconverts it into sesquioxide, and this again yields its oxygen to a fresh portion of organic matter, so that sesquioxide of iron is a most powerful oxidizing agent, it being, in fact, the condenser of oxygen and the medium of its conveyance to and destruction of organic substances. MM. Chevreul and Kulhmann have also shown that sulphate of lime acts in a similar manner, namely, that it yields its oxygen to the elements of organic substances, and is thus converted into sulphuret of calcium, which, having a great affinity for oxygen, is again rapidly converted into sulphate of lime, and thus the oxygenation and destruction of the organic matter is effected. Mr. Millon has published an interesting paper on the formation of nitre, or nitrate of potash through the ammonia generated during the destruction of organic substances being oxidized into nitric acid, which combines with potash, if present, and if not, with lime or magnesia, which are present in all soils. Mr. Millon has remarked that this important chemical reaction is effected by an organic substance called humic acid, which acid, or its homologues, exists in large quantities in all earthly loams containing much organic and more especially vegetable matters in a state of decomposition. Humic acid absorbs the oxygen of the atmosphere, which oxidizes the ammonia into nitric acid and water. The chemical theory of the destruction of organic matters through oxidation, and their absorption of plants and reconversion into the same substances from which they were derived, such as sugar, starch, gum, oil, essences, &c., or albumen, fibrine, gluten, caseine, &c., was greatly in favor a few years since, as it appeared to fulfil all the requirements of nature. It has, however, been greatly shaken by the beautiful researches of M. Pasteur on fermentation, putrefaction, and spontaneous generation, which proves clearly that these physiological actions play a most active part in the destruction of organic substances. This most skilful chemist has demonstrated that there is no such thing as spontaneous generation, and that the notion entertained by some physiologists, that if matter is placed in favorable circumstances as to heat, light, &c., and in a proper medium, it will become spontaneously

animated, is undoubtedly erroneous, and that life in all instances proceeds from a germ or egg in which the vital principle is implanted by the Creator. He proves that life, even in the most insignificant of microscopic creatures, always originates thus, and that there is no single instance of matter being animated by purely physical causes. Let me draw your attention to a few among many facts observed by M. Pasteur, proving that life is not a property of matter, like weight, electricity, compressibility, &c., but is always the result of a germ, even in its lowest development.

When arterial blood is carefully introduced from the artery into a clean vessel, and there brought into contact with oxygen, no fermentation or putrefaction of the blood ensues; and if the experiment is repeated, substituting for the chemically prepared oxygen atmospheric air which has been passed through a tube containing pumice-stone and carried to intense heat, in this case also there is no putrefaction or fermentation; but if ordinary atmospheric air be used in the place of pure oxygen or heated air, and left in contact with some of the same blood, this vital fluid will rapidly putrefy, which is doubtless owing to the presence in the atmospheric air of the sporules or eggs of micoderma and vibrios, or organized ferments, which give rise to the various chemical phenomena and changes of organic matters into products which characterize fermentation and putrefaction. The same results are obtained when fresh urine is substituted for blood, an important fact, proving that the germs of fermentation do not exist in the fluids themselves, and that fermentation does not proceed from any molecular or chemical change in the composition or nature of the organic substances contained in blood and urine, but that the ferment from which these phenomena proceed is to be sought for in the atmosphere. I shall substantiate this view by several other interesting observations made by M. Pasteur.

If some asbestos is heated to a red heat and plunged into a liquor susceptible of putrefaction, such as a saccharine liquor, no fermentation ensues; but if atmospheric air is passed through asbestos at natural temperature, and the latter then immersed in a similar solution of sugar, active fermentation soon takes place, proving that the atmospheric air has left on the surface of the asbestos sporules of the micoderma vini, which being introduced with the asbestos into the saccharine fluid, originated the well-known alcoholic fermentation. Another beautiful series of experiments by M. Pasteur is the following: He introduced into 60 small balloons a small quantity of a highly putrescible fluid, and after boiling the fluid in order to drive out the remaining air in the balloons by the formation of steam, he closed the small apertures, so that on cooling the steam condensed and a vacuum was produced. He then proceeded to open 20 of these balloons at the foot of one of the hills of the Coté d'Or, 20 others at the summit of the same, (about 2000 feet high,) and the remaining 20 at a point near Chamounix, and the following results were observed: Of the first 20 balloons, the contents of 15 entered into putrefaction within a few days; of the second 20 only 6; and of the third 20 only 2 gave signs

of fermentation. These results, as well as some others, published by M. Pasteur, prove that the sporules or germs of putrefaction and fermentation exist in all parts of the atmosphere, but more abundantly in the lower strata, which are necessarily in contact with great quantities of organic matter in a state of decay, and that these sporules become scarce in the upper regions, which are further removed from the source of pollution. Further, he has proved, as I stated in my last lecture, when speaking of the preservation of milk, that fluids extremely liable to fermentation or putrefaction may be prevented from entering into those conditions by heating them to 250° or 260°, a temperature at which the sporules cannot resist decomposition in the presence of water. M. Pasteur has advanced a step further in this interesting inquiry, for he has demonstrated that there are two distinct phases in putrefaction. In the first there are the vibrios produced in the bulk of the fluid containing animal matters in solution, and these microscopic animals unfold the organic substances into more simple compounds; in the second phase, there are produced on the surface of the fluid cryptogams, which he calls mycoderms, and which absorb oxygen from the air, and oxidize the products developed by the vibrios. In the case of the fermentation of vegetable substances, such as saccharine matters, there are mycoderms, (*Mycoderma vini*,) which unfold them into, say, alcohol and carbonic acid, while other mycoderms (*Mycoderma aceti*) are produced, and grow on the surface of the fluid, oxidizing the alcohol into water and acetic acid. He therefore concludes that the animal vibrios and vegetable mycoderms exist abundantly in nature, and that they must be and are the most active causes of the destruction of vegetable and animal substance which have fulfilled their vital function on the earth, reducing them into water, carbonic acid, ammonia, sulphuretted hydrogen, &c., which, in their turn, become the foods of a succeeding generation of plants and animals. We may, therefore, truly say that death is life in the constantly reviving world.

M. Pasteur has observed another most curious fact connected with these microscopic beings, (I say microscopic, because it requires a most powerful instrument and high powers to distinguish them, and to ascertain that vibrios possess a vibratory motion while mycoderms are stationary,) this is, that vibrios are the only animals which can live in pure carbonic acid, and which are killed by oxygen even diluted with another gas. Oxygen is essential to the life of mycoderms, and some of them can also exist in carbonic acid. Lastly, M. Pasteur has noticed that if a very small amount of yeast is added to a saccharine fluid, the yeast will not materially increase in quantity, because the new generation which is produced lives on the remains of its parents; but if phosphate of ammonium or of lime and some sal-ammoniac is added with the yeast, the latter will rapidly increase and occupy several times its original bulk. It is curious to observe that these microscopic cryptogams require the same kind of food as man. Thus, they require nitrogenated food—so do we. They require mineral food, as phosphates—so do we. They require respiratory food—so do we. They produce carbonic acid as part of their vital functions—so

do we. I cannot do better than conclude this part of my subject by giving the following table descriptive of the various ferments observed by M. Pasteur:

FERMENTATION.

Mycoderma vini.	Unfolds sugar.	Alcohol. Carbonic acid. Succinic acid. Glycerine.
Mycoderma aceti.	Oxidizes alcohol.	Acetic. Water.

PUTREFACTION.

Infusorial Ferments.

Vibrios unfold animal substances.

Bacteria oxidizes organic matters of an animal origin.

I should mislead you, however, if I did not call your attention to another class of fermentations, which are chemical in their nature and in their action. This, for example, is the case when bitter almonds are crushed and mixed with water. The amygdaline they contain is decomposed into prussic acid, hydruret of benzoil, &c., by the ferment they contain, which is called emulcine. Again, when black mustard is reduced to meal, and placed in contact with water, the myronic acid it contains is decomposed into the essential oil of mustard, a most corrosive fluid, and this is also effected by a special ferment called myrosine. Again, when malt is mashed with water of a temperature of 170°, its starch is converted into sugar by a ferment called diastase. We also know that the starch which we take into our stomachs as food is converted into sugar by animal diastase, which exists in the saliva as well as in the pancreatic juice, and that this conversion is identical with that which takes place in the mash-tub. In fact, the whole of the changes which our food undergoes to render it fit for assimilation in the digestive organs of the body may be considered as a series of different fermentations. What gives a further interest to those chemical ferments is, that not only are they all nitrogenated, and possess a chemical composition, but they present many identical properties, still each has its own peculiar action; that is, it will only cause fermentation in those matters which have been placed by nature in contact with it. Thus diastase will not convert amygdaline into prussic acid, hydruret of benzoil, &c., nor will myrosine convert starch into sugar.

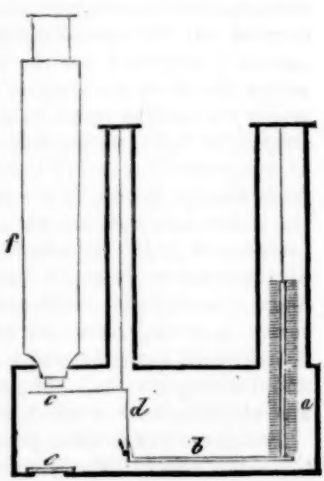
In conclusion, it is certain that our knowledge of these interesting phenomena of putrefaction, fermentation, &c., is yet in its infancy, and there is no doubt that many important discoveries in this intricate branch of knowledge will, from time to time, be brought before the world, and reward science for its persevering efforts.

[This lecture concludes Dr. F. C. Calvert's course as delivered before the Society of Arts; on delivery, they were listened to with eagerness by a numerous auditory, and have now been read with no less pleasure than instruction.—ED. *C. N.*]

Magnetic Declination. By Dr. JOULE.

From the London Mechanics' Magazine, May, 1865.

At the ordinary meeting of the Literary and Philosophical Society, March 21, 1865, R. Angus Smith, Ph. D., F. R. S., President, in the chair, Dr. Joule described an instrument he had constructed, for showing rapidly minute changes of magnetic declination. The adjoining cut represents a section of the instrument. *a* is a column of small magnetic needles suspended by a filament of silk. Attached to its lower end is a glass lever *b*, with a hook at its end. A fine glass lever *c* is suspended by a single filament of silk, its shorter arm being connected with the first lever by means of a small hook attached to the fibre *d*. The whole is enclosed in a stout copper box, into which light is admitted through a lens *e*, cemented into an orifice immediately under the object-glass of the microscope *f*. The microscope magnifies about 300 linear, and has a micrometer in its eye-piece, with divisions corresponding to $\frac{1}{100}$ths of an inch. One division corresponds to a deflection of the needle of $4\frac{1}{2}''$; and as a tenth of a division can be very readily observed, the instrument measures deflections to within half a second. So rapid is the action that, on applying a small magnetic force, the index takes up its new position steadily in two seconds of time. Besides being a damper to the motion of the needle, the copper box, by its conducting power, equalizes the temperature rapidly, so that the indications are not to any considerable extent disturbed by currents of air. The success of the present instrument encourages the hope that very much greater delicacy may be obtained by a further multiplication of the motion and the use of a more powerful microscope. Dr. Joule stated that he had observed an extensive magnetic disturbance the previous evening, the index being driven entirely out of the field of view.



The President said that three meteorological instruments of true originality and of unprecedented delicacy had been described to that Society by the inventor, Dr. Joule. For common observation, the instruments were too refined, but in some fields of inquiry they seemed the only hopeful guides. Manchester had not yet a Meteorological Observatory, although the proposal had often been made to establish one. Private spirit, as in the instance of Mr. Vernon and others, had made the necessity less felt than before. But there was now an opportunity of beginning one with entirely new apparatus of Manchester origin, which would probably very much alter the quality of the inquiries made in meteorological establishments.

Mr. Baxendell stated that the Society had in its possession a thermometer constructed by the late Dr. Dalton, and which, it is believed, was used by him in many of his meteorological observations. The scale has the initials "J. D." and the year "1823" engraved upon it; and the freezing and boiling points of water are indicated on the stem by fine file marks. As it is known that the zero points of thermometers sometimes change to the extent of one or even two degrees in the course of several years, it occurred to Mr. Baxendell that it would be interesting to ascertain whether any change had taken place in this thermometer, and he had, therefore, lately tested very carefully the position of the freezing point, but found that no sensible alteration had taken place; and he believed, therefore, that great confidence might be placed in the observations which Dalton had made with this instrument.

For the Journal of the Franklin Institute.

Aboriginal Ingenuity.—The Tepiti.

Indications that American Indians were an original, and, to a certain extent, an isolated race, are to be found in mechanical devices which they had, as in others which they had not; absence in one case and their presence in the other being hardly reconcilable with foreign communication or intercourse. Tribes that became the most advanced carried out the thread-making idea without the *distaff* and *pendant spindle*; they had not the *bellows* nor *scissors*, nor is it certain that either the *domestic lamp* or *candle* was known. The Maya MS. dictionary is said to mention a "hanging star," supposed to refer to a suspended light, perhaps in the temple. Then, there is no indication of the potter's wheel in their crockery ware. Now, could any people from Europe or Asia have made anything like an early settlement on the continent, and not have introduced one or more of these? and if introduced could they have vanished without leaving a trace of one of them north or south, east or west? We learn from Garcilasso la Vega how delighted his countrymen, the Peruvians, were with scissors. A young Inca told one of his school-fellows that the Spanish deserved all the gold and silver in the country for introducing them and looking-glasses. The native mode of cutting the hair with flint and obsidian knives was tedious and painful.

But there are devices peculiar to American Indians which speak to the same effect. Early colonists on the Atlantic or Pacific coast, or inland, would be alive, as new colonists ever are, to native devices, and ready to adopt such as had advantages over their own, and such they would naturally send or take to their own people. Now, among others, there is one that could not have escaped the observation of even transient visitors or settlers, and one so novel, simple, and efficient that, if the knowledge of it ever reached Europe or Asia, it would certainly have been preserved to this day. I refer to *the Tepiti*, or Cassava press, as interesting an example of primeval ingenuity as sacred or profane writers have ascribed to oriental inventors.

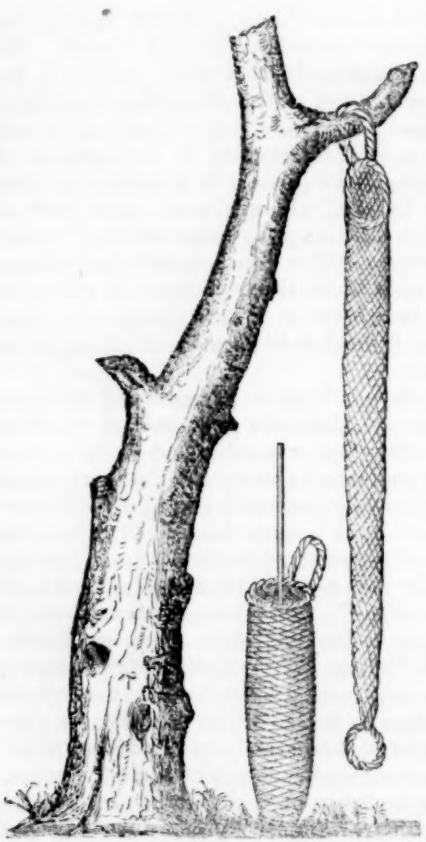
Were all the contrivances of untutored tribes collected together, they would present a greater range of research, and inventions more beautifully simple, than we are apt to imagine. Some are such as science is glad to adopt, many which she is slow to supersede, and others, as the boomerang, that she is puzzled to explain. Barbarian patriarchs of our species were the parents of the arts; spinning and weaving rose with them; elemental metallurgy and earthen ware are theirs. The chisel and drill, the hatchet and adze they gave us, and from them the most precious of primitive conceptions was received—the means of producing and using fire. In their condition they evinced as fine talents for invention as have their descendants under more favorable circumstances. With them every device was original, and the arts of civilization are, in the main, improvements on their suggestions,—expansions of their ideas. We build on a foundation they laid, and cultivate a field they began to plant.

Amid the furor attending modern inventions, primitive ones are neglected, much as letters are by those who have learned to read. We inherit the mechanical alphabet from barbarians, and, considering the times, places, and circumstances in and under which the elements of the world's machinery were disclosed, an account of their origin and early applications would form a brilliant chapter in the romance of history and of the first rude struggles of genius. If scholars can learn nothing from childrens' "first lessons," the wild man's horn book of inventions may be consulted with advantage by those who are in quest of new ideas or even new principles. The Tepiti, a very ancient contribution of some mechanical Cadmus of the tropics, is an example. Having had occasion recently to refer to it, I have thought, as illustrating a principle little known or used, a description of it might be usefully suggestive to inventors.

On their discovery the red race was found in possession of two chief elements of vegetable food; one the seeds of a grass, *maize*, the other the roots of a shrub, *cassava*. The first was cultivated in the temperate, the second in the warmer zones, and throughout the same parallels they are still prepared and used by the natives as by their ancestors immemoriably. Every one knows how northern Indians pounded their corn in mortars, and how often, among other relics turned up by the plough, stone implements for that purpose occur. The treatment of the southern product was different. The mandioca, or cassava root, is a species of potato, resembling, in its long, irregular figure and dimensions, the sweet potato. It cuts like our Mercers, white, firm, watery, and somewhat fibrous. It is cultivated as extensively throughout Spanish and Portuguese America as maize is with us. Farina prepared from it resembles in appearance and qualities our Indian meal. It is "the bread of Brazil." There slaves live chiefly on it, and planters, merchants, and all classes have it always on their tables. In the process of converting the root into flour, a higher and more varied order of mechanical resource was displayed by primitive millers of the south than is revealed in the "corn-crackers" or "bread-pounders" of the north.

The root is first washed, scraped, and then grated to a pulp. This they do on a slab of wood prepared by smearing over one side with a thick gum, in which they insert a multitude of sharp particles of flint or granite broken up for the purpose. The gum hardens like stone and produces a rasp or grater that lasts a life time. On one of these a root is rubbed down in a moment, and when any required quantity is thus treated, in order to get rid of the poisonous water, the pulp is put into the Tepiti, a coarse, basket-like tube, made of thin splits of cane or bamboo, three-fourths of an inch wide and rather loosely interwoven. (See figure.)

A common size is five feet long, five to six inches diameter at the mouth or open end, and three or four at the bottom or closed one. A large loop, or a couple of strong withes, is formed at each end. When used, the first thing is to wet it if dry. The operator then grasps the edges of the mouth with both hands, and, resting the bottom on the ground, throws the weight of his body on the basket till he has crushed it down to about half its previous length or height, and, consequently, swelled out its diameter. A smooth stick, like a broom-handle, is then introduced, the pulp put in and packed round it till the basket is filled. It is then suspended from a hook or the limb of a tree and a heavy stone or basket of stones fastened to the bottom, the weight of which stretches the tube till it becomes longer than at first. The capacity, of course, diminishes with the extension, and the contracting sides press the pulp against the unyielding stick and squeeze out the water. Instead of stones one end of a log of wood is inserted into the lower loop and loaded with a papoose or two, or anything else at hand, or the squaw herself puts a foot in the stirrup and serves as the weight.



Such is the Cassava press, an invention dating back to the earliest settlers of Central and South America, or coeval with their knowledge of the root. It was as

common among the Caribs of the Islands as it was and is with Indians on the Amazon and Orinoco, and throughout the vast regions from Mexico to the Plata. In Brazil there are those who prefer it to screw presses imported from Lisbon and Malaga at a cost from two to three hundred dollars. I purchased one at a venda, for sixteen cents, of the above dimensions, and for it the Indian manufacturer probably received only three or four, certainly not over five or six. It is used by planters on the Amazon for expressing oil from cantanha nuts.

If there is a current primitive invention evincing closer and happier reasoning out of common tracks, we know not where to look for it. Nor is that all; fabricated before metals or tools were known, Indians still bring it out of the woods with little but their hands to produce it. Were it proposed to compare the amount of originality and ingenuity in two aboriginal devices, representing the eastern and western hemispheres, I would select the Tepiti. Confront it with the analogous original one of the old world, the wine-press common throughout Egypt in her highest estate: a sack filled with grapes and twisted in contrary directions as washerwomen wring out wet linen. A stick was thrust through or attached to each end. They were turned by four men, two at each stick. Had the Tepiti ever been known there, it would most likely have been found figured with the foregoing at Thebes or Beni Hassan, and at Herculaneum or Pompeii with screw and wedge presses of the Romans.

The capacity of the basket decreasing as the length increases may not be instantly obvious to every one. Without reflection it might be supposed that extension in one direction would compensate for diminution in the other, that if elongation reduced the diminution one-half and at the same time doubled the length, the capacity would be little affected. The action and effect are, however, perceived by supposing the instrument made of a highly elastic material, india rubber, for example. It might then be stretched till the sides came together and formed a solid thread.

I am told the difference between a low and wide measure and a high and narrow one is not unknown, among others to proprietors of drinking saloons, as appears from the substitution of tall and tapered glasses for old Dutch-bottomed ones, over which they soar, that the change is a literal deduction from and a profitable application of the principle by which the cassava pulp is squeezed in the Tepiti. Admitting this, it is but one of a thousand interesting instances of physical principles little known creeping almost imperceptibly into extended use. It shows how pecuniary interest makes men of different professions active, though unconscious, promotors and elucidators of them. It is the working of the same beneficent law which in the natural world "from seeming evil still educes good." Thus, cupidity, awake to new chemical and mechanical facts, and alert in applying them to every purpose that promises to pay, is an efficient diffuser of useful knowledge. Like the rapacious instinct in some of the lower tribes, it contributes to the general good, and, as with them too, its eagerness occasionally leads to disappointment and loss. E.

New York, December, 1865.

*On the Decay of Gutta Percha and Caoutchouc.** By Prof. William Allen Miller, M. D., F. R. S.

From the London Artizan, December, 1865.

The inquiries to which this investigation has given rise have extended over many months, and have included a large number of analyses, but the results obtained may be stated in a small compass, as they are very definite. I have examined numerous samples of gutta percha cables, both injured and sound, which have been in use for several years, and I find in all cases that the deteriorated portions have undergone chemical change, and that change consists in a process of *oxidation*.

Whatever retards or prevents this oxidation, retards or prevents the decay of the gutta percha, some of the specimens which I examined being as good as new, though they had been manufactured and used electrically for years, whilst others in a few months had become brittle, rotten, and unserviceable. As the general result of these inquiries, I find that when the gutta percha has been completely submerged in water no injurious change has occurred, sea water appearing to be eminently adapted to the preservation of the gutta percha. On the other hand, alternate exposure to moisture and dryness, particularly if at the same time the sun's light has access, is rapidly destructive of the gutta percha, rendering it brittle, friable, and resinous in aspect and in chemical properties. A gradual absorption of oxygen takes place, and the gutta percha slowly increases in weight, becoming at the same time proportionately soluble in alcohol and in dilute solutions of the alkalies. In every instance, however, some portion of the gutta percha remained unchanged in composition.

My experiments have also been extended to the prolonged action of air, moisture, and light upon india rubber, and here also I find that these agents effect analogous changes, though somewhat less rapidly.

The caoutchouc, however, instead of becoming brittle, is converted into a glutinous mass, losing its elasticity, increasing in weight to a certain extent, and becoming partially soluble in alcohol and diluted alkaline liquids.

These deductions are made from the examination of a number of samples supplied to me partly by Captain Galton and Mr. L. Clark, including specimens of coated telegraphic wires suspended in air, specimens of submarine cables, specimens of wires sunk in the soil under various conditions, besides experiments instituted by myself upon the action of various agents upon gutta percha, and they include the results of an extended and well contrived series of experiments made at the works of the Electric Telegraph Company, under the direction of Mr. L. Clark.

I will here subjoin an abstract of the principal experimental details,

* A paper on this subject by Mr. Spiller having recently appeared, it has been thought that the Fellows might be interested in an official report made five years ago to the Joint Committee appointed by the Lords of the Committee of Privy Council for Trade and the Atlantic Telegraph Company, to inquire into the construction of submarine telegraph cables.—*Ed. Jour. Chem. Soc.*

and, for the convenience of reference, will arrange them under the following distinct heads:

1. Experiments upon pure gutta percha.
2. Experiments upon commercial gutta percha.
3. Experiments upon submerged cables.
4. Experiments upon decayed and damaged cables exposed in air and underground under various circumstances.
5. Experiments upon caoutchouc.
6. Experiments upon other compounds.

1. *Experiments on pure gutta.*—Pure gutta differs in some of its properties from the commercial gutta. I found on examining the whitest samples purified by Dr. Cattell, that it formed a porous milk-white mass, wholly soluble in benzol, in ether, in bi-sulphide of carbon, and in the ordinary solvents of gutta percha. It is a perfectly pure hydro-carbon, probably containing $C_{20} H_{30}$. I found it to consist of—

	Found.		$\overline{C^{20}} H^{30}$.
Carbon, . . .	88·96	or	88·88
Hydrogen, . .	11·04	"	11·12
	100·00	"	100·00

When exposed to a temperature of 212° it softens but does not liquefy; it loses a trace of moisture, and then gradually absorbs oxygen, becoming brown, brittle, and resinous in appearance. In one specimen the increase in weight amounted to 4·45 per cent. The oxidized portion is insoluble in benzol, which when digested on the brown mass dissolves out a quantity of unaltered gutta, which had been protected from oxidation by the coating of resin.

This resinous mass, when thus purified, was found to have been produced from the gutta percha by simple absorption of oxygen, the gutta having in one experiment absorbed more than a fourth its weight of oxygen from the atmosphere.

2. *Chemical experiments on commercial gutta percha.*—The gutta percha of commerce is not a pure proximate vegetable principle, but it consists chiefly of a hydro-carbon which may for brevity be termed *pure gutta*, or simply gutta, mixed with a product of its oxidation, which is in the form of a soft resin, amounting to about 15 per cent. in the best commercial samples.

The following is the composition of a piece of ordinary good commercial gutta percha, taken from a piece of new cable supplied to me by Mr. L. Clark:

Pure gutta, ...	79·70
Soft resin, ...	15·10
Vegetable fibre, ...	2·18
Moisture, ...	2·50
Ash, ...	0·52
	100·00

The moisture reported in this analysis is mechanically diffused through the mass of the gutta percha, and seems to have some influence upon its pliability and toughness. 100 parts of the commercial

sample, when dried at 212° till it ceased to lose weight, deducting the ashes, contained:

Carbon,	84·66
Hydrogen,	11·15
Oxygen,	4 19
	100·00

This gutta percha softens and liquefies by a heat of 212°. It is soluble, with the exception of a few flocculi of fibrous matter, in benzol, in bi-sulphide of carbon, and in ether. Alcohol dissolves none of the pure gutta, but extracts a portion of the soft resin. This resin is an oxidized compound, probably in a transitional condition to a higher stage of oxidation. I found it to consist of—

Carbon,	76·15
Hydrogen,	11·16
Oxygen,	12·69
	100·00

The true gutta was extracted nearly pure from this sample by dissolving it in benzol, filtering, and adding alcohol, when a coagulum of pure gutta was obtained, which was found to consist of—

Carbon,	87·22
Hydrogen,	12·04
Oxygen,	0·74
	100·00

The presence of the small quantity of oxygen in this case was due to a little of the resin which still adhered to the precipitated mass of gutta.

Commercial gutta percha may be preserved for months, and even years, with little change, either in water or in air, provided light be excluded. This I have found from my own experiments, and the results which I have myself obtained are confirmed by experiments made by Mr. Clark. The following are some of the most important of these experiments: 500 grs. of thin sheet gutta were exposed under various conditions at the end of last October at the Electric Cable Works. The various samples were examined on the 2d of July of this present year (1860).

1. In netting, exposed to sun and rain in open air.
2. In a bottle, open to the air and light but excluded from rain.
3. In a bottle, open to the air but excluded from light.
4. In fresh water, open to air and light.
5. In fresh water, open to air excluded from light.
6. In fresh water, excluded from air and light.
7. In sea water, exposed to air and light.
8. In sea water, excluded from light but exposed to air.
9. In sea water, excluding both light and air.

The specimens 4, 5, 6, 7, 8, and 9 were wholly unaltered, with the exception of a slight increase in weight, due to the absorption of water, which they lost again after exposure to the air for an hour or two. The tenacity and structure of the material did not appear to have undergone the slightest change.

No. 2, which had been folded up and introduced into a bottle, the mouth of which was open and inverted, had increased in weight from 500 grs. to 524·5 grs., or about 5 per cent., owing to absorption of oxygen from the air. The outer layers of the sheet, where exposed to light, were brittle and resinous in appearance, but the inner portion, which had been screened from light by the outer folds, was but little altered in texture or appearance.

On examining chemically a portion of the most brittle part, I found a large portion of it to have lost the composition of gutta, and to have become converted into a matter soluble in alcohol, 55 per cent. of the mass being in fact transformed into the resin already spoken of.

The sample No. 3, which had been kept in the dark, had experienced little or no change. It had only increased 2·5 grs. in weight, or 0·5 per cent., and when treated with alcohol gave up 7·4 per cent. of resinous matter to it.

These results agree with those which I made upon gutta percha which had been exposed to the light of day for the shorter period of two months. This specimen had become quite brittle, had increased in weight 3·6 per cent., and yielded 21·5 per cent. of resinous matter soluble in alcohol; whilst a piece of the same sheet kept in the dark had undergone no sensible change.

Samples of sheet gutta percha were also subjected in November last to the action of the following liquids and exposed to diffused daylight:

A. Boiled linseed oil.	C. Stockholm tar.
B. Linseed oil not boiled.	D. Coal tar.

When examined on the 4th of August, 1860, or at the end of nine months, these liquids were found not to have exerted any perceptible solvent action upon the gutta, which retained its texture and tenacity in all those portions which had been fairly submerged in the liquid and protected from the light and atmospheric air; but in those portions which had projected into the atmospheric air contained in the jar, where it was also exposed to the effects of diffused day-light, the texture had become rotten, and the material more or less brittle and resinous.

All the liquids above-mentioned are calculated to exclude oxygen from the gutta percha, and thus they are enabled to exert a preservative influence upon it, without, however, in any degree softening or dissolving its texture. Hence they are likely to be highly valuable agents in coating the insulating material.

(To be continued.)

Furnace Slags.

From the London Mechanics' Magazine, September, 1865.

Dr. F. G. Finch read a paper "On the Utilization of Blast Furnace Slags." He said, within the last two or three years, by a process of slow cooling, a durable artificial stone had been produced at several iron works in France and Belgium, and was used for building purposes and as paving stones for roadways. The result had been satisfactory in

a pecuniary point of view. Having recently visited most of the places where the stone was produced, he would describe the plans adopted. The slag was allowed to run from the furnace in a fluid state into pits in the ground, eight or nine feet in diameter at the top, with sides sloping inwards to the bottom, the pits being three feet deep in the centre. The liquid hardened on the top, and the hardened mass rose as the pit filled. The furnaces were tapped every eight hours. The mass in the pits took nine or ten days to cool. It was quarried by means of large hammers and iron bars. The material thus obtained, except the crust on the top and a thin layer at the sides and bottom, was a hard, compact, crystalline stone, often resembling certain basalts. Of course, its quality depended on the nature and proportion of the materials with which the furnace was charged. That produced from cinder iron did not equal that produced in the manufacture of grey pig. The stone was found to have a high degree of resistance to crushing. It was largely used in France for paving, and was worked by masons into pieces of the form and size desired with facility, while the waste thus obtained was employed for macadamized roads. He had seen it where it had been laid down for three years. The French engineers spoke favorably of it, and the iron masters showed him proofs that, while this process got rid of a cumbersome material, it was itself a profitable branch of industry. The great consideration in England to such a manufacture would be the space it would require. With three tappings a day, each tapping filling one pit, and ten days for cooling, 30 pits would be needed, which would require a space of 2400 square feet. It was not often that so large a space could be made available at our iron works; but, on the other hand, it should be remembered that France was very deficient in stone suitable for paving.

Proc. Brit. Asso.

On the Hydraulic Properties of Magnesia. By M. H. Ste. Claire-Deville.

From the Proceedings of the Academy of Sciences of Paris.

About seven years ago, M. Douy, an Engineer of the Salt-Spring Company of the North, sent me some magnesia obtained by calcining the chloride of magnesium. It was a product of the processes invented by M. Balard for the utilization of the mother-waters of the salt springs, put in practice in France and also at Strassfurt in Prussia, in mines from which there is at present extracted considerable quantities of the chlorides of magnesium and potassium, and of sulphate of soda.

This magnesia, which was anhydrous and in compact lumps, was left for several months in the running water under a hydrant in my chemical laboratory at the Normal School. It assumed a remarkable firmness, became hard enough to scratch marble, of which it had the density and tenacity, translucent in thin pieces like alabaster, and crystalline in geodes, which were formed in the interior of the mass. After six years of exposure to the air, this material is in no wise altered, and its analysis gave me the following results:

Water,	27·7
Carbonic acid,	8·3
Alumina and oxide of iron,	1·3
Magnesia,	57·1
Sand,	5·6
Total,	100·0

The small quantity of carbonic acid found in this material shows that it is essentially formed of a crystallized hydrate, and that this hydrate, like brucite, does not attract carbonic acid and form a carbonate.

To prove that this is the case, I prepared very pure magnesia by calcining the nitrate at a low red heat, and pulverized the mass finely enough to make with water a semi-plastic mass, which I allowed to remain for some weeks in boiled distilled water enclosed in a tube hermetically sealed.*

The magnesia gradually combined with the water and assumed a hardness and compactness comparable with those of my former specimens. It also became crystalline and translucid. After drying in air it had the following composition:

Water,	31·7	30·7
Magnesia,	68·3	69·3
Total,	100·0	100·0

It was, therefore, a simple hydrate of magnesia. I made with this substance, medals cast as with plaster, and they set under water, presenting the appearance of marble.†

The magnesia of M. Balard, when calcined at a bright red heat, has hydraulic properties, which show themselves with a wonderful rapidity and perfection. Calcined at a white heat for twelve hours, pulverized and made into a paste, it does not set unless it be left for several weeks in contact with the air, and even then it hardens slowly, so that its hydraulic properties appear to be almost lost.

A mixture of chalk, or of marble, and of magnesium pulverized, furnishes with water a slightly plastic paste, which moulds well and gives, after remaining some time in water, products of very great solidity. I intend to try this material for casting busts in artificial marble, the qualities of which may be very important if my expectations are fulfilled. All my experiments have been made heretofore with a mixture of equal parts of marble and magnesia.‡ Fontainebleau sandstone gives with

* If the pulverised magnesia be tightly packed at the bottom of the glass tube, and water poured on it, the tube will soon be broken by the formation of a compact hydrate of greater volume than that of the calcined magnesia.

† I speak here only of the magnesia obtained by calcining the chloride or the nitrate of magnesium. As to the light magnesia prepared by means of the hydrocarbonate, it gives on hydration a less tenacious talcose product, to which I shall refer again.

‡ M. Damour has published in the *Bulletin de la Societé Geologique* (2d series, vol. iv., 1846) the analysis of a mineral, predazzite, composed like my artificial stones, of carbonate of lime and hydrate of magnesia. M. Damour considered this substance as formed by a mixture in which the carbonate of lime is cemented by the hydrate of magnesia. My experiments confirm manifestly this explanation. Predazzite is composed of carbonate of lime 63, hydrate of magnesia 35·1, foreign substances 11·9.

magnesia a product still more remarkable on account of the grain which it has and its strength.

Plaster of Paris mixed with magnesia undergoes alteration under water and diminishes its hydraulic properties.

My experiments on these mixtures suggested to me the idea of calcining, at a temperature of from 300° to 400°, (572° to 752° Fahr.,) dolomites tolerably rich in magnesia, to make them into paste with water and try them as cements. These materials differ from poor lime only in having been cooked at a temperature far below that of the kilns, and they have properties essentially differing from them. The dolomite treated at a low temperature set under water very rapidly, and gives a stone, the hardness of which is really extraordinary. The specimen which I have the honor to submit to the Academy was prepared with the dolomite which Messrs. Bell of New Castle, employ for making magnesia by the Pattinson process.

If the dolomite is heated more strongly, so that a little lime is formed in the mass, this lime does not yet interfere with the setting, but it separates in fine crystalline veins which are perfectly pure arragonite and free from magnesia. The crystals of this carbonate are perfectly visible under the lens and are all prismatic so as to leave no doubt as to their form. The complete absence of carbonate of magnesia from this material proves once more the correctness of my brother's observations upon the incompatibility of lime and magnesia when their compounds assume certain crystalline forms.

When dolomite is heated to redness the carbonate of lime is transformed into quick-lime, and the product entirely calcined, pulverized and made into a paste immediately loses all consistence in water.

In all these experiments the magnesia is the hydraulic material which cements, as it hydrates, the particles of intact carbonate of lime, exactly as in artificial mixtures of magnesia and marble, and makes a compact and homogeneous stone.

M. Paul Michelot has been kind enough, at my request, to expose all these magnesium materials to the action of the sea, at Boulogne, and up to this time, after a long trial, they have resisted. But these experiments are not yet finished, and I desire to leave this skilful engineer to publish his final results.

Other experiments have been tried, at my suggestion, upon feebly heated dolomites. According to the brief report which M. Michelot has been kind enough to make to me, they entirely confirm my results. The facts contained in this note prove the perfect hydraulic character of pure magnesia by the formation of a definite hydrate. They explain the successful attempts of M. Vicat to introduce magnesia into marine cements; and permit me to hope that by means of them the arts may utilize a substance which has been, thanks to the admirable processes of M. Balard, put at their disposal at a low price and in indefinite quantities.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, January 17th, 1866.

The meeting was called to order with the President, Wm. Sellers, in the chair.

The minutes of the last meeting were read and approved.

The minutes of the Board of Managers were reported, including the following donations to the library: From the Massachusetts Institute of Technology, Boston, Massachusetts; Charles Cologné, Esq., Washington, D.C.; Professor John F. Frazer and the American Philosophical Society, Philadelphia.

The Annual Report of the Board of Managers was then read and accepted.

The minutes of the Standing Committees were reported, and the Special Committee on experiments in steam expansion reported progress.

Secretary's Report.

Mechanics.—In a paper read before the Institute of Mechanical Engineers, by Mr. David Greig, it is stated that the means of applying steam power to purposes of cultivation have been so far improved as to render this process practically successful under the conditions most favorable to its operation. The improvements which have in a marked manner contributed to this result are: 1st. The "clip-drum" for giving motion to the wire rope by which the cultivating implement is moved. In this apparatus the rope is seized, in passing over the drum, by self-adjusting clips, which grasp it firmly at either side, thus preventing it from being flattened, and giving it sufficient hold with one turn, where otherwise, four would be required. 2d. The use of steel wire rope, which possesses remarkable strength. 3d. An ingenious contrivance for taking up the slack and preventing the rope from dragging, which action was found to increase the resistance tenfold. 4th. The use of *strong* rather than *light* engines. The peculiar wedging action of the plowshare was found to be far more efficient than any produced by rotary cutters.

The Volta prize has been awarded to Fresnel for the invention of a new electric lamp, very superior in its structure to any hitherto used. The carbon points are not only caused to approach each other as they are consumed, but are also separated if they come too close, this action being accomplished by two clock movements, (tending to produce opposite motions,) one or other of which is liberated at a time by an escapement, controlled by an electro-magnet whose force varies with the quantity of the current passing, and is thus very sensitive to any change in the distance of the points.

A piece of apparatus was lately exhibited in England, invented by a Mr. Kirk, in which water was frozen by the expansion of previously condensed and cooled air.

In connexion with this statement, Mr. Coleman Sellers remarked: An apparatus of this kind was made in Cincinnati thirteen or fourteen

years ago, intended for New Orleans, and was put in successful operation. I was present at the time the experiments were made. The reservoir for air was very large, twelve feet long by forty-eight inches in diameter, made of heavy boiler plate. Air was forced into this by a beam engine. The air being forced into this vessel, the heat generated by the compression was allowed to pass off, and the air then allowed to expand in a vessel, where the freezing was accomplished, part of the force existing in the compressed air, however, being utilized in an intermediate cylinder. The greatest difficulty encountered was in making a boiler which would be air-tight at high pressures. The air leaked through the substance of the iron. By some means, however, possibly by coating with copper or tin, a thoroughly air-tight vessel was obtained.

It is stated that Carré's apparatus for obtaining cold by the use of ammonia has been applied with success to the extraction of a double chloride of magnesium and potassium from the mother liquor left in the salt pools in which sea-water has been evaporated at Montpellier, in the south of France.

An improvement in the Lenoir gas engine by M. Hugon is mentioned, which consists in an arrangement by which the explosive mixture in the cylinder is ignited by small gas jets, which are themselves relit in turn, when extinguished, by another. This obviates the numerous inconveniences and expenses arising from the use of a battery and induction coil, as in the original machine.

Clay for moulding may be rendered permanently moist, according to a writer in the *London Mechanics' Magazine*, by using a strong solution of chloride of calcium.

In a catalogue of apparatus by the famous French maker Salleron, presented to the Institute by that gentleman, and kindly forwarded, with other valuable and interesting matters, by Mr. James Swaim, we notice, among other things, the drawings and description of a very curious piece of apparatus, illustrating the action of the Giffard Injector. A cylindrical glass reservoir with metal ends, in one of which is an inward opening valve, is placed horizontally, with a small air-gun, supplied with air from the same reservoir, pointed exactly at the valve. The reservoir is charged by a condensing air-pump, the chamber of the gun receives its supply from this, a ball is placed in its barrel, and then it is discharged, whereupon the ball is driven against the valve which it opens, and enters the reservoir against a pressure exactly equal to that which caused its own motion.

Chemistry.—A new application of paraffin has been made by Dr. Stenhouse, of England. He mixed that substance with a few per cent. of linseed oil, and then saturates with this mixture canvas for tents or awnings and like materials, thus rendering them water-proof. Leather treated in a similar manner has great advantage when made into boots and shoes, as it is freed from the destructive action of alternate wetting and drying.

Mr. Barrett observes that sand paper will emit a phosphorescent light for some moments after a hydrogen flame had played upon it.

A new process for obtaining caustic soda is announced by Mr. A.

G. Hunter, of England. Sulphate of soda in solution is mixed with burned lime and subjected to great pressure, when, according to this gentleman, sulphate of lime will be formed and caustic soda left in solution.

Thalium has been found in notable amount, by Bunsen, in the water which has been used for washing the pyrites of Rammelsberg, at Juliushutte, and by Professor Bischoff, of Lausanne, in an ore of manganese, which contains as much as one per cent. of thalium.

The editor of the *British Journal of Photography* speaks with high approbation of the rectified wood spirits or methylic alcohol as a solvent for gun-cotton, in place of the mixture of alcohol and ether now used in the preparation of photographic collodion.

Gun-cotton is being largely used in California and Nevada. At the new Almaden Quicksilver Mines it is very extensively employed. Mr. C. E. Hawley, the chief engineer, says that its most valuable property is its freedom from smoke, which leads to a great saving of time in the works, as the miners are not obliged to wait for some time that the smoke may clear away after firing blasts, as is the case with gunpowder.

A brass, composed of 60 parts copper, 38 zinc, and 2 of iron, is said to bear forging at a red heat, and to resist a breaking strain of 27 tons per square inch.

A very curious experiment, illustrating the manner in which platinum will cause the formation of certain chemical compounds by its mere presence, is published by the German chemist, K. Kraut. Oxygen gas is caused to pass in bubbles through some aqua-ammonia contained in a flask, in which is hung a spiral of platinum wire heated red-hot. Under these circumstances heavy fumes of nitrite of ammonia will be formed, developing heat enough to keep the wire red so long as the flow of oxygen and supply of ammonia from the solution lasts.

(This experiment was here performed by the Secretary.)

Mitscherlich, at the conclusion of a paper in which he recounts the results of a long and elaborate study of the metalloids with the spectroscope, states his opinion to be that all these bodies are not elements but compounds.

To amalgamate dirty zinc plates for a galvanic battery, set them in a dish with 3 ozs. common muriate acid, 1 drachm of a saturated solution of corrosive sublimate, and ½ oz. of mercury, and smear the mercury over the plate.

The Commissioners of the Belgian government have reported favorably as to the efficiency and inoffensiveness of a new gunpowder for blasting, manufactured by Messrs. Schäffer & Budenberg, of Buckau, Magdeburg, and Manchester.

In the last number of the *Philadelphia Photographer* is a very interesting article On the Solar Spectrum, by Professor Rood of New York. Among other facts noticed is this curious one, that blue and yellow, mingled by rapid motion, as this disk turned by the whirling machine, will not produce green, as is commonly supposed, but flesh color. (This fact was demonstrated by experiment.)

A very simple and ingenious method of demonstrating some of the actions concerned in wave motions, owes its development to this same gentleman. Two glass slides, capable of moving in the ordinary magic lantern, are covered with black varnish. On one of these a series of equal and equidistant vertical lines are scraped clear, while upon the other a single horizontal wave line is in like manner produced. These plates being placed together in the lantern, a wave line will be shown on the screen made up of detached blocks. If, now, the slide having the undulating line on it be moved horizontally, a progressive motion of the wave will be shown without any progression of the individual particles.

(This arrangement was then exhibited.)

A glass photograph of a part of the solar spectrum, made by Mr. L. M. Rutherfurd of New York, was then shown in the lantern, and its relative position in the spectrum described; the fact also being noted that these photographs showed twice as many lines as were to be found in the elaborate plates of Kirchoff.

Professor Fairman Rogers then presented to the meeting a photograph on glass of the moon, made also by Mr. L. M. Rutherfurd of New York, and remarked, in connexion with this subject, that Mr. Rutherfurd had succeeded in producing more perfect pictures of the moon than any other experimenter, either in this country or abroad. These were obtained by the use of a telescope expressly arranged for this purpose, whose lenses had been corrected for the more refrangible or actinic rays by Mr. Rutherfurd himself. The correction was accomplished by a process of local grinding; constant experiments being made by means of photography to determine from time to time what effect was being produced upon and what was yet needed by the lens. The greatest credit is due to Mr. Rutherfurd for the time and care, as well as skill, which he has devoted to the construction of this instrument, and to its use.

At the conclusion of these remarks the Tellers of the Annual Election for Officers, Managers, and Auditor, to fill the vacancies of those whose term of office has expired, reported the result as follows:

President, William Sellers.
Vice President, (three years,) John H. Towne.
Secretary, Henry Morton.
Treasurer, Frederick Fraley.

MANAGERS.

(For one year.)
William B. Bement.
Edward Y. Townsend.

(For two years.)
John Rice.

(For three years.)

Washington Jones.
Charles H. Cramp.
Pliny E. Chase.
Charles S. Close.

James S. Whitney.
James Dougherty.
J. Vaughan Merrick.
Robert C. Cornelius.

AUDITOR.

Samuel Mason.

The meeting was then, on motion, adjourned.

H. Morton, *Secretary.*

Annual Report of the Board of Managers of the Franklin Institute for the Year 1865.

In accordance with the By-Laws, the Board of Managers presents its Annual Report of the condition of the affairs of the Institute.

Soon after the beginning of the last year, an examination was made of the present Institute building, and the advantages and drawbacks attending a change of location were fully discussed. From the considerations thus made apparent, it was determined to execute extensive alterations and repairs, by which the present building might be rendered adequate to the purposes of the Institute, and attractive to those whom it was designed to accommodate. The execution of these alterations and improvements was placed in the charge of a committee, and with the beginning of the summer, when the building was less used than at other seasons, this work was commenced.

Notwithstanding the unprecedented difficulty in securing skilled labor which has marked the last season, these improvements have progressed in a satisfactory manner, and may be now said to approach completion, and have cost about $7000. The work accomplished may be briefly expressed as follows:

A substantial and permanent slate roof has been put upon the whole building. The library and reading room has been enlarged so as to afford *additional* case room nearly equal to its whole original capacity. This change was demanded by the condition of the books, which were placed two deep in nearly all the cases, with additional crowding, which rendered any complete systematic arrangement out of the question. Large additions of new and important works have been made to the contents of the library, and the whole arranged in a convenient and accessible manner. The reading room and adjacent offices have been entirely refurnished, and rendered not only comfortable but highly attractive in their appearance and accommodations.

The lecture room has received most extensive alterations; each of the ascending platforms constituting the floor surface have been widened to secure comfort to the audience, and furnished with cane-seated chairs in place of the wooden benches formerly in use. A new lecture table, containing a large leaden pneumatic cistern properly furnished with inlet and outlet pipes, has likewise been added, and the space in rear of this increased to a depth of twenty feet, by which means optical experiments and illustrations of other subjects by optical apparatus may be developed with a facility and success equalled nowhere in this city. The whole arrangement for lighting this room has been reconstructed and proves itself both efficient and admirably under control. The laboratories adjoining the lecture room have been thoroughly repaired, furnished with new cases, with gas and water supply, and with an evaporating closet so as to answer efficiently to the demands of modern experimentation.

Lastly, the cellars of the building have been cleaned, opened, and repaired, and supplied with two furnaces of the most improved construction for heating the lecture and reading rooms.

By the report of the Treasurer it will be seen that the receipts and payments during the past year have been as follows:

Balance in the Treasury, January 1, 1865,	$ 310 91
Receipts during the year,	39631 79
	39942 70
The payments have been—	38940 08
Leaving a balance in the Treasury, January 1, 1866, of—	$ 1002 62

The indebtedness of the Institute is—

Amount of 5 per cent. loan,	$ 12250 00
Interest due theron,	4325 00
Temporary loan,	2500 00
	$ 19075 00
Annual interest payable on 5 per cent loan,	612 50

The number of life members now on our list is 616, and of contributing members in good standing 629, to which should be added 58 holders of stock of the second class, and 30 holders of 10 or more shares of the first class, who are not also life members, making the total number of members 1433.

The number of new members elected during the year is—		122
Of stockholders having members' privileges,.		88
Total,		210
Members resigned,	59	
" died,	34	93
Leaving a total gain during the year of—		117

It is to be recommended to all the members and friends of the Institute to secure, if possible, the disposal of the entire stock of the Institute, by which its permanent success would be placed upon a secure basis. It is also to be remembered by holders of stock, that they not only enjoy the advantages of the Institute at a cheaper rate than members, but have beside an ownership in the Institute. The holder of ten shares enjoys likewise all the privileges of membership, without the payment of any annual fee, and may besides bequeath this privilege to his survivors or assign it to another.

WILLIAM SELLERS, *President.*

A Comparison of some of the Meteorological Phenomena of DECEMBER, 1865, *with those of* DECEMBER, 1864, *and of the same month for* FIFTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	December, 1865.	December, 1864.	December, for 15 years.
Thermometer—Highest—degree, .	63·00°	59·00°	71·00°
" date, .	27th.	7th.	2d, '59.
Warmest day—mean,	55·33	52·33	62·80
" " date,	4th.	3d.	2d, '59.
Lowest—degree, .	17·00	12·00	4·50
" date, .	15th.	12th.	19th, '56.
Coldest day—mean,	21·67	19·67	11·00
" " date, .	15th.	12th.	18th, '56.
Mean daily oscillation,	11·23	9·83	12·11
" " range, .	6·85	7·37	6·48
Means at 7 A. M., .	35·34	32 92	32·03
" 2 P. M., .	40·82	38·58	39·31
" 9 P. M., .	36·95	35·95	34·84
" for the month,	37·70	35·82	35·39
Barometer—Highest—inches, .	30·424 ins.	30·411 ins.	30·678 ins.
" date, . .	23d.	9th.	18th, '56.
Greatest mean daily press.	30·399	30·362	30·611
" date, . .	23d.	9th.	18th, '56.
Lowest—inches, . .	29·493	29·071	28·946
" date, . .	21st.	21st.	9th, '55.
Least mean daily press.,	29·535	29·275	29·175
" date, . .	1st.	21st.	9th, '55.
Mean daily range, .	0·205	0·265	0·215
Means at 7 A. M., .	29·945	29·801	29·950
" 2 P. M., .	29·899	29·730	29·907
" 9 P. M., .	29·946	29·782	29·936
" for the month, .	29·930	29·771	29·931
Force of Vapor—Greatest—inches,	0·509 in.	0·438 in.	0·551 in.
" date, .	27th.	7th.	2d, '59.
Least—inches, .	·068	·052	·025
" date, .	22d.	12th.	18th, '56.
Means at 7 A. M., .	·177	·152	·146
" 2 P. M., .	·180	·161	·168
" 9 P. M., .	·182	·169	·157
" for the month,	·180	·161	·157
Relative Humidity—Greatest—per ct.,	97·0 per ct.	92·0 per ct.	100·0 per ct.
" date,	27th.	2d.	often.
Least—per ct.,	33·0	26·0	23·0
" date, .	5th.	1st.	15th, '61.
Means at 7 A. M.,	80·7	77·3	77·4
" 2 P. M.,	64·3	64·8	65·2
" 9 P. M.,	76·7	74·8	75·1
" for the month	73·9	72·3	72·6
Clouds—Number of clear days,* .	6	3	8·5
" " cloudy days, .	25	28	22·5
" Means of sky cov'd at 7 A. M.,	74·8 per ct.	73·2 per ct.	64·7 per ct.
" " " " 2 P. M.,	61·6	77·7	63·7
" " " " 9 P. M.,	60·0	77·7	49·1
" " " for the month	65·5	76·2	59·2
Rain and melted snow—Amount,	5·677 ins.	4·754 ins.	3·842 ins.
No. of days on which rain or snow fell,	12	19	10·7
Prevailing Winds—Times in 100,	N68°27′W ·239	S72°54′W ·158	N62°39′W ·268

* Sky one-third or less covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of the YEAR 1865, *with those of* 1864, *and of the last* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57¼′ N.; Longitude 75° 11¼′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	1865.	1864.	14 years.
Thermometer—Highest—degree, . .	97·00°	96·00°	100·50°
" date, . . .	July 7th.	June 26th.	July 21st '54
Warmest day—mean,	87·33	89·67	91·30
" " date,	July 28th.	June 26th.	July 21st '54
Lowest—degree, . .	3·50	4·00	—5·50
" date, . . .	Feb. 13th.	Feb. 17th.	Jan. 23d '57
Coldest day—mean, .	12·00	7·00	—1·00
" " date, .	Feb. 13th.	Feb. 17th.	Jan. 9th '56
Mean daily oscillation,	12·40	13·79	14·85
" " range, .	5·52	5·27	5·53
Means at 7 A. M., . .	52·10	50·40	49·93
" 2 P. M., . .	60·47	59·66	59·92
" 9 P. M., . .	54·74	53·75	53·30
" for the year, .	55·77	54·60	54·38
Barometer—Highest—inches, . . .	30·424 ins.	30·411 ins.	30·704 ins.
" date, ...	Dec. 23d.	Dec. 9th.	Jan. 28th '53
Greatest mean daily press.,	30·399	30·362	30·611
" date, ...	Dec. 23d.	Dec. 9th.	Dec. 18th '56
Lowest—inches, . . .	29·141	29·071	28·884
" date, ...	Jan. 7th.	Dec. 21st.	Ap. 21st '52
Least mean daily press., .	29·226	29·150	28·959
" date, . . .	Oct. 19th.	Nov. 4th.	Ap. 21st '52
Mean daily range, . . .	0·152	0·152	0·155
Means at 7 A. M., . . .	29·852	29·772	29·878
" 2 P. M., . . .	29·811	29·730	29·838
" 9 P. M., . . .	29·846	29·775	29·865
" for the year, . .	29·836	29·759	29·860
Force of Vapor—Greatest—inches, .	0·917 in.	0·895 in.	1·059 in.
" date, . .	July 25th.	Aug. 2d.	June 30th '55
Least—inches, . .	·044	·022	·013
" date, . . .	Feb. 13th.	Feb. 17th.	Feb. 6th '55
Means at 7 A. M., .	·348	·314	·325
" 2 P. M., .	·361	·321	·340
" 9 P. M., .	·364	·338	·345
" for the year, .	·358	·324	·337
Relative Humidity—Greatest—per ct.,	100·0 per ct.	100 0 per ct.	100·0 per ct.
" date, .	Feb. 23d.	Jan. 18th.	often.
Least—per ct., .	23·0	18·0	13·0
" date, . .	April 24th.	Mar. 9, Ap. 7	Ap. 13th '52
Means at 7 A. M.,	73·9	72·0	75·5
" 2 P. M.,	57·7	53·9	57·2
" 9 P. M.,	70·9	68 9	71·9
" for the year,	67·5	64·9	68·2
Clouds—Number of clear days,* . .	101	94	108
" cloudy days, . .	264	272	257
Means of sky cov'd at 7 A. M.,	62 3 per ct.	61·8 per ct.	60·1 per ct.
" " " 2 P. M.,	62·7	66·6	60·9
" " " 9 P. M.,	45 9	52·4	45·8
" " for the year,	57·0	60·2	55·6
Rain and melted snow—Amount, . .	53·637 ins.	46·730 ins.	46·022 ins.
No. of days on which rain or snow fell,	1 19	128	127
Prevailing Winds—Times in 1000,	s89°52′w·213	s82°22′w·220	x76°38′w·206

* Sky one-third or less covered at the hours of observation.

A General Abstract of the Meteorological Observations made at Philadelphia during the year 1865.—By Professor JAMES A. KIRKPATRICK.

Latitude 39° 57½′ N. Longitude, 75° 11¼′ W. from Greenwich. Height of barometer fount, sixty feet above mean tide in the Delaware River.

1865. Months.	Thermometer.									Barometer.								Dew point.			
	Maximum.	Minimum.	Range. Monthly	Range. Mean daily.	Mean daily oscillation.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average	Highest.	Lowest.	Range. Monthly	Range. Mean daily.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average
	°	°	°	°	°	°	°	°	°	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	°	°	°	°
January,	51	6	45	7·14	11·90	22·85	29·90	26·85	26·53	30·315	29·141	1·174	·234	29·843	29·795	29·828	29·822	18·05	19·59	20 33	19·32
February,	56	3½	52½	5·97	11·34	28·45	36·20	32·44	32·36	30·322	29·256	1·066	·205	29·872	29·849	29·875	29·865	21·63	23·70	24·20	23·17
March,	76	24	52	6·72	13 97	42·03	52 40	46·16	46·86	30 210	29·185	1·025	·188	29·825	29·777	29·826	29·809	33 65	34·89	35 42	34·65
April,	79	40	39	5·99	14·33	51·25	62 03	54·48	55·92	30·265	29·404	·861	·172	29 897	29·844	29·889	29·877	40·13	42·66	41·87	41·55
May,	84	46	38	6·60	13·81	59·87	68·91	61·39	63 39	30·147	29·405	·742	·126	29 742	29 708	29·740	29·730	50·27	50·71	51·99	50·99
June,	93	61	32	4·52	13·23	73·79	83·28	74·73	77 26	30·069	29·589	·480	·081	29 854	29 821	29·841	29·839	64·89	66·54	65·84	65·76
July,	97	63	34	4·44	12·13	74·76	83·44	76 66	78·29	30·141	29·537	·604	·089	29·766	29·752	29·771	29·763	64·06	63·71	65 05	64·27
August,	91	58	33	3·29	12·13	72·10	81·02	74·56	75·89	30·141	29·540	·601	·089	29·847	29 814	29·847	29·836	62·21	63·17	63·58	62·99
September	89	49	40	4·81	11·90	70·73	77·85	73·42	74·00	30·225	29·583	·642	·109	29·950	29·888	29·933	29·924	63·25	64·04	64·64	63·98
October,	78	37	41	5·13	11·23	52·55	60·15	54·85	55·85	30·225	29·155	1·070	·171	29·778	29 746	29·786	29 770	42·98	41·68	43·52	42·73
November	66	26	40	4·73	11·63	41·43	49·63	44·45	45·17	30·405	29·395	1·010	·156	29·901	29·837	29·877	29·872	33·77	35·00	35·17	34·65
December,	63	17	46	6·85	11·23	35·34	40 82	36·95	37·70	30·424	29·403	1·021	·206	29·945	29·899	29·946	29·930	29·91	29·09	30·11	29·70
Annual means,	97	3½	93½	5·52	12·40	52·10	60·47	54·74	55·77	30 424	29·141	1·283	·152	29·852	29·811	29·846	29·836	43·73	44·56	45·14	44·48
Winter,	59	3½	55½	6·83	11·02	28·07	34 89	31·75	31·57	30·411	29·071	1·340	·235	29·839	29·791	29·828	29·819	22·00	23·48	24 37	23·28
Spring,	84	24	60	6·44	14·04	51·05	61·11	54·01	55 39	30·265	29·185	1·080	·162	29·821	29·776	29·818	29 805	41·35	42·75	43·09	42·40
Summer,	97	58	39	4·08	12·50	73·55	82 58	75·32	77·15	30·141	29 537	·604	·086	29 822	29 796	29 820	29·813	63·72	64 47	64·82	64 34
Autumn,	89	26	63	4·89	11·62	54·90	62·54	57·57	58·34	30·405	29·155	1 250	·145	29·876	29 824	29 865	29·855	46·67	46·91	47·78	47·12
Means 14 years,	100½	—5½	106	5·53	14·85	49·93	59·92	53 30	54·38	30·704	28·884	1·820	·155	29·878	29·838	29·865	29 860		43·36		